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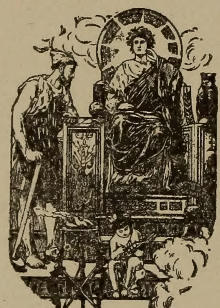

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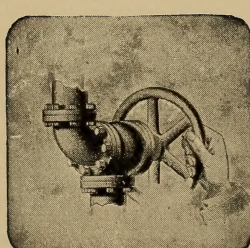

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J. H. Harris

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FROM MINE TO MINT.

By M. C. Ihlseng, E. M., C. E., Ph. D.

"SILVER is in veins and gold has a place where they fine it." So early in the history of the world as in the days of Job was the geology and metallurgy of the royal metals understood. Crude and primitive as were the processes employed, yet the principles established by these hand-workers, so long ago, still remain and, in this, the age of machinery, underlie the various "iron wonders of man's ingenuity."

In the ancient mines found in the mountains of Zaba, in Ethiopia and in the Sinaitic region, we may read the story which is to-day familiar to every miner,—the story of doubt and transition, of hope and fruition. The romance of mining with the wild freedom of life in the camp, is fast passing away and giving place to the conventionalities of civilization as the cruder methods are being supplanted by the carefully operated systems of the present. Nevertheless there is a peculiar sense of unreality in the lives of those engaged in the arduous task of delving for riches,—a sort of dream-life which renders the prose of an otherwise dreary existence endurable, even enjoyable. Perhaps it is the ever-present hope of fortune that casts this glamor; or, is it living so near to nature's heart? Sure it is that there, among the mountains, nature reveals herself to man in a thousand varying moods and phases. While one may grow accustomed to his surroundings, they nevertheless tinge his dreams with their own hue, be it rosy or gray. The most of our mines are located amid scenery unsurpassed in beauty and grandeur by any in the world, and to a tenderfoot coming, as in the case of the author, direct from the sea level with its flat, long stretches and gentle verdure-clad slopes, the first view is never to be forgotten and leaves an impression which not even long residence in the mountains and a perfect familiarity with their moods can ever efface.

It was in the early dawn of a bright June day that the revelation burst upon my wondering eyes. Against the cerulean gray of a western morning sky towered crags innumerable and, beyond, as far as the eye could reach, rose peak upon peak in tumultuous contempt of perspective, their battlemented tops seeming to bid defiance to the inevitable forces of nature. To the north were conical summits over 14,000 feet above the level of the sea which had withstood the elements more effectually than their neighbors and showed more perfect outline between the rifts in the dense clouds, partially hiding their terraced flanks. So fortress-like did these appear that one could easily fancy the flashes and roar of a progressing storm as proceeding from heavy artillery hidden in their embrasures. Southward the hills presented a bleaker aspect.

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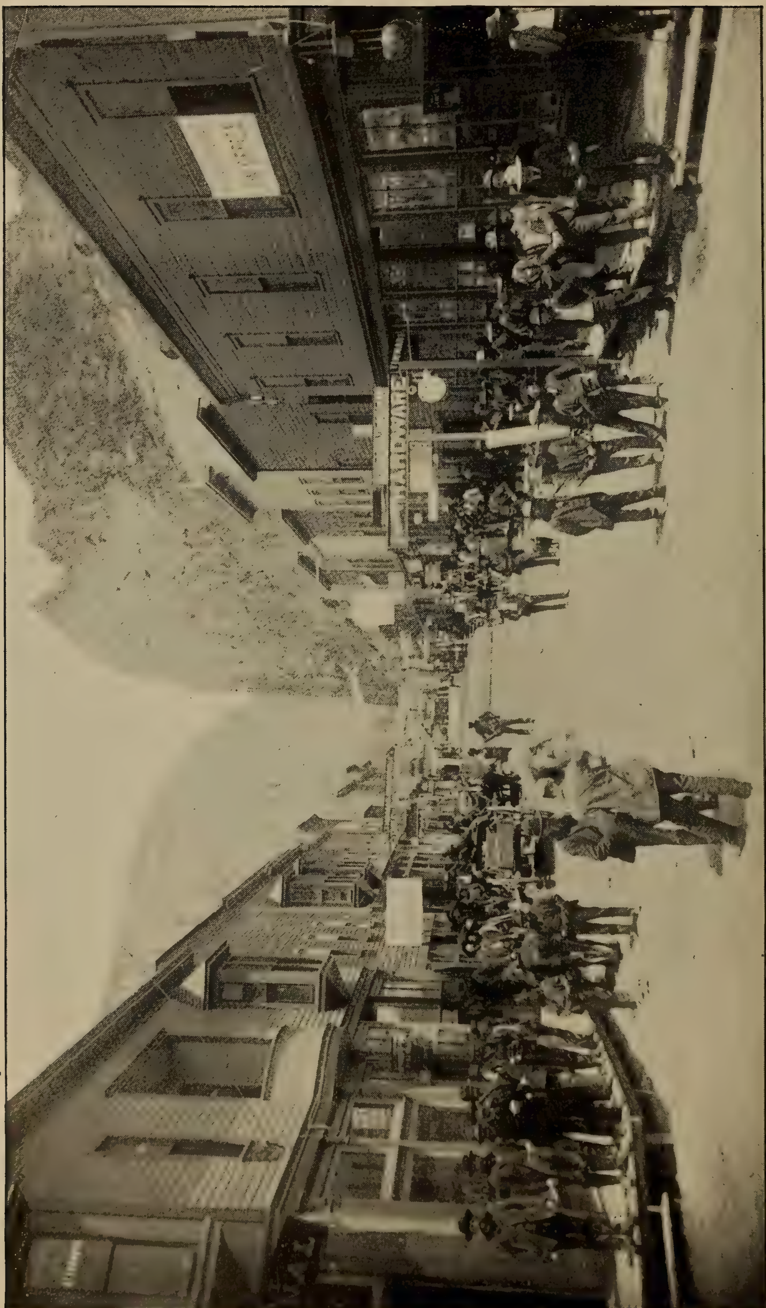
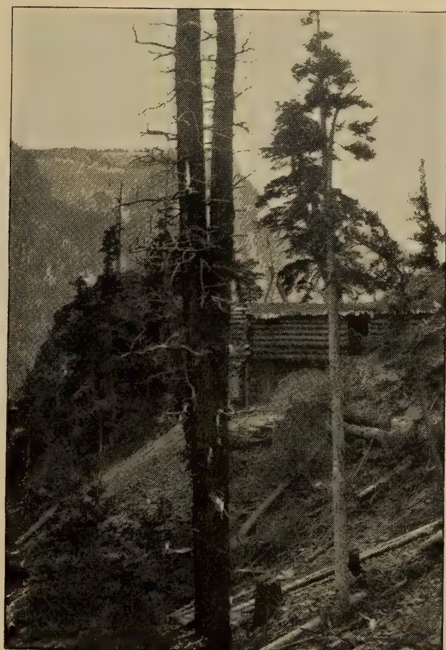


THE MAIN STREET IN CREEDE, COLORADO.

Their slopes were not gentle, and neither verdure nor foliage offered contrast to the sombre-hued rock. Abruptly rising from the mass, hundreds of feet high, was a display of cyclopean columns and walls which might well be conceived the forum and fastness of all the gods of war. Some formed wide amphitheatres, while others enclosed great blue lakes of unknown depth and wondrous crystal clearness; hither and yonder would be seen bright boisterous streamlets plunging downward over rocks and bowlders in a wild frolic to the outer world.

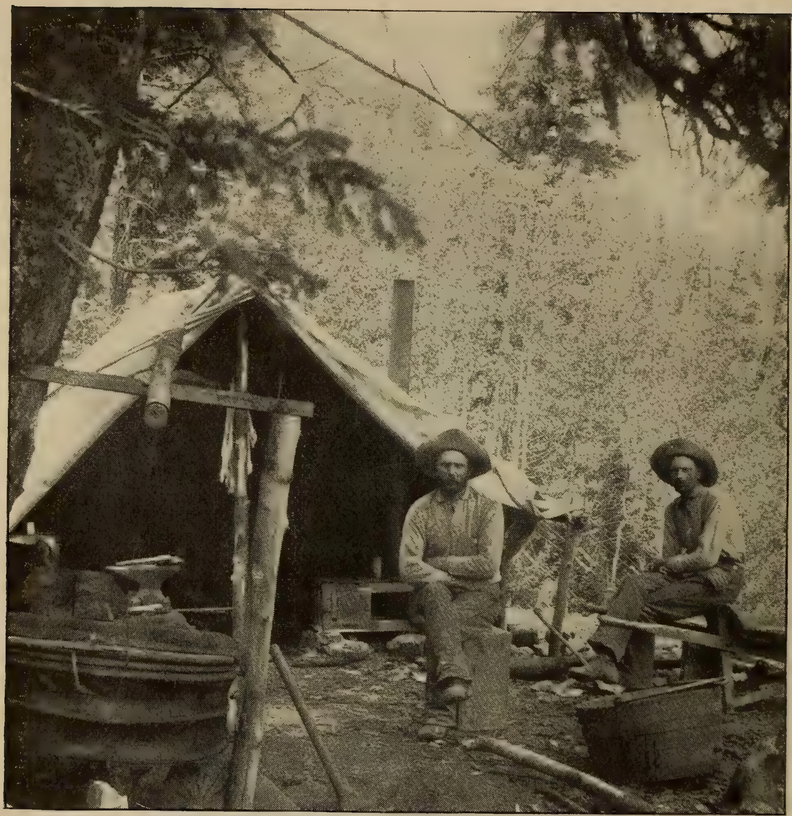
Here and there, in bold relief, were dykes of eruptive matter trending over gulch and hill. As often, also, did sags persist across the country indicating the presence of decomposable metals underneath. The eye was at times arrested by gorgeous chromatic displays in "squirts of crimson and golden sunlight," inviting the prospector from afar with the promise of reward, rich and yellow, like the rainbow's pot of gold, only not so elusive. Here the mineral, as if weary of its bonds, had burst to daylight and covered the gray volcanic rocks with an oxidized mass, in hues so brilliant and varied that no artist's hand could copy them. On all sides, though it was June, were large patches of snow, some to disappear before October, but many to resist another summer's heat as they had already withstood the myriads of suns since the glacial epoch. A thousand feet below was "timber-line," distinctly marking the upper limits of forest growth, and beyond were fair valleys, the home of the Ute and Arapahoe, from whom, strangely enough, the treasures of the mountains are still hidden.



THE HOLY MOSES MINE. SCENE OF FIRST DISCOVERY OF SILVER AT CREEDE, COL.

Except for the blue smoke curling from the gloomy iron chimneys of boilers, an occasional horseman or a pack-train of burros carrying supplies to, or ore from the mine, there was little sign of life amid all this solemn grandeur. Miners' cabins lined the hill-slopes in close proximity to numerous abandoned incipient mines whose cavings have buried many extravagant hopes and wasted fortunes. Along the gulches were deserted and decaying mills, idle wheels and crumbling chimneys to attest the tentative progress of the mining industry.

Locked within these mountain ranges lie the secret vaults of Nature's diversified mineral wealth. Some of her coffers have been discovered in the few isolated mining districts whose names are familiar; a few are but half explored, while many yet remain sealed and undisclosed to man. In the mighty convulsions of nature, following the dead calm of the tertiary period, rocks were rent in every direction. Innumerable vents and craters were formed, through which belched forth prodigious eruptions of lava that highly metamorphosed the strata of the earth, submerging immense areas. The subsequent cooling and contraction opened fissures of various widths and of greater or less extent. Some of these filled up again with molten igneous matter and are



A PROSPECTOR'S CAMP.

called dykes, but many more became the repositories for mineral. The ultimate source or origin of the metals is a matter of conjecture only. One school holds that, rising from the centre of the globe in a gaseous or molten state, under favorable conditions they were condensed. Another believed in the subterranean growth or reproduction of the minerals. Linnaeus wrote that "mineralia crescunt," and the belief is still held by some that gold grows ; but the generally accepted theory involves the aqueous transportation of mineral, leached out of igneous rock and deposited in the fissures to form veins.

As "silver is in veins" the entire production of that metal is secured by delving for it and mining it out of the crude rock ; and that in a form in nowise resembling the pure metal, but as a mineral, resulting from a chemical combination with other elements. Save a few large accumulations, termed bonanzas, the silver minerals are widely diffused in flakes and specks among the minerals of the base metals. The notable exceptions to the rule include the rich mines of Norway, Peru and the Lake Superior region, producing the precious metal in leaves and nuggets, free from any admixture, mechanical or chemical ; the largest mass of free silver being that discovered in Sonora, Peru, weighing 2700 pounds.

Gold occurs sparsely diffused throughout the volcanic rocks disseminated in the quartzose matter of veins in conjunction with other materials, or scattered in beautiful arborescent forms of octahedral crystals in the foliations of the slates. Its minerals are few in number and very rare. Of the 6,010,-000 ounces of the world's annual pro-

duction of gold, less than 50,000 ounces are recovered from its minerals, the balance being derived from the "native" or free gold. Perhaps one-fourth of the preseat gold product comes from these veins; the remaining three-fourths are recovered from the detritus of the mountains washed down every hill and scattered along every stream by the interminable action of mighty waters. Seldom do these gravels and sands fail to carry some gold, but it is in regions of abundant gold veins or "reefs" that the auriferous segregations are rich with metal in pellets of all sizes, up to that of the famous Donolly nugget, weighing 2520 ounces, beside which its exhausted discoverer starved to death. It was these alluvial deposits, called placers, which constituted the original attraction that populated mountain wastes, extended the art of mining and added millions to the wealth of nations.

During the year previous to the discovery of the auriferous gravels in the bed of Sutter Creek, California, by James W. Marshall, the annual gold product of the world was about 2,080,000 ounces, mainly derived from Russian placers. That discovery precipitated a rush to the Pacific Coast that moved the United States west. For here, lying in the sands of the gulches, was gold; gold requiring only simple appliances for exploration, no money for development and no process for refining. With pick, shovel and wheelbarrow the miner removed the gravel to a rocker, where he patiently sifted the fine rock from the coarse, washed the light sand from the heavy, and finally drained the black grains from the sparkling metal. Verily it was a poor man's diggings! Each knew at nightfall how much of the current coin of the realm he had gathered during the day. The rocker soon gave way to the sluice, which lessened the work of transportation, and revolutionized gold-washing methods. On the bed rock of the stream were placed long, narrow boxes, overlapping each other, with strips fastened on the bottom at certain intervals. These, with the aid of mercury, gathered the gold from the rushing waters.

For fully a decade California's gulches maintained a marvelous production and equaled the output of all the rest of the world, but by '59 the bonanza placers had "bottomed out," and the yearly product of this prince of metals fell off until it assumed a certain degree of permanence at about 750,000 ounces this source. With the decline of gulch mining came, *pari passu*, the necessity for more economic systems of working the low grade gravels. From this arose the hydraulic process of mining.

Corporations bought up abandoned claims for miles together, and constructed ditches and pipe lines, carrying large streams of water from great distances and heights. With the aid of giant nozzles whole hillsides were cut away and washed into sluices, the gold being saved with more system and completeness. Installations were set up to wash gravels of so low a grade that it would seem to entail only loss of time and money, were not the highest type of

engineering employed. Reservoirs that cost upward of $60,000 each delivered water for the various companies to flumes and ditches, many of which were over forty miles long, two, about 125 miles long, costing at least $10,000 a mile. One pipe line had over 14,000 feet of pipe 22 to 30 inches in diameter, costing $3 per foot. Thousands of miner's inches of water were discharged under high pressure, tearing away banks averaging only a grain of gold to the cubic yard (3c. per ton), and washing the soil into sluices.*

The refuse from "hydraulicking," composed of sand, loam, and pulverized quartz, was swept down the creeks, and lodged in the canyons and valleys below. With the high waters of spring it overflowed the irrigated soils of adjoining farms and became a constant source of contest until the operation was decreed, by the U. S. Circuit Court, illegal, and was prohibited by legislation. Without some means of disposing of the debris, the system is an impossibility and could not be maintained. The passage of the bill, at present before Congresss, which contemplates appropriations for the construction of dams to confine the debris and to prevent further floods, will rehabilitate the industry and again swell the production of stream gold.

With the disappearance of placer mining, many who had staked all on their "hope in the sands," left the gulches and valleys, and climbing higher, sought for the veins which supplied the drift. Soon the cabin of the prospector became a familiar sight, and the "claims" staked off were numbered by the thousands. This pioneer of legitimate mining, who has unlocked for the nation her vast strong-houses of wealth, is a peculiar product of an industry fraught with danger, full of privations and fickle to the last de-

*A miner's inch is the unit of "wet measure," arbitrarily established in early days. It may be defined as the stream of water which would be discharged from an opening one inch square, with a pressure of six inches above the opening, and is equivalent to nearly 673 gallons per hour.

THE "LAST CHANCE" MINE AT CREEDE, COL.

A MINER'S HOME IN THE MOUNTAINS.

gree. His cabin, or tent, being established, he carefully examines the region for outcroppings or other signs of mineral deposits. If satisfied with his "find," he announces a claim by means of a stake bearing a legend descriptive of the direction and length of the ground desired. This gives him possessory right to ten acres or less, and notifies all comers of pre-emption; otherwise, he moves on, ever in pursuit of the *ignis fatuus*. Sleeping amid snows, suffering untold exposure with a fortitude worthy of a nobler cause than the greed of gold, ever confident of success, no danger deters him. Like the delicate lace-like weed, called "tumbler," or "traveler," that is uprooted and carried with every breeze, touching here and there, the prospector is a curious prototype of the migratory spirit of the West. So, among the rugged hills the indomitable prospector exposes the metalliferous deposits which centuries of the Indian's possession of the lands have failed to reveal. That these natives did not secure for themselves the transcendent riches of the mountains, is a wonder to many. But Earth gets her price for what she gives —a price the noble red man deemed too high. In the words of Chief Severo, "Trees don't work, God don't work, Indian don't work, white man works." And surely it does require work. Neither witchery nor magic charm will entice the mineral, and in nature's conservation of energy, an ounce of metal produced requires its equivalent of labor.

Going down into the mine is indeed a thrilling experience and one rather overwhelming to the "tenderfoot." Enveloped in suits of waterproof, with hats of oilskin, and provided with candles, a party ready for the descent presents a gruesome spectacle, reminding one forcibly of certain conceptions of Doré. The cage, which serves for both passenger and freight, rises to a level with the floor of the shafthouse, and is simply a platform of wood with uprights and framing of iron. This fits closely in the shaft, being lowered and raised by means of machinery puzzling enough to the interested stranger, with its drum, sheaves, cable and various safety appliances. To take a position on that little square of wood, feeling that on this machinery "which does sometimes break, you know," hangs all one's hope, requires some courage. A ray of comfort is derived from the assurance of the foreman that this same cage has safely carried down and up all the delvers below with never an accident yet. With the warning "elbows in" the cage drops. With a gasp one reaches wildly about to find nothing to hold to in that damp darkness, growing so dense as that square "hole of daylight" diminishes so rapidly, and down we glide, through trickling waters without jar and in utter silence till, with a thud, the cage stops, 2500 feet underground.

The dim candle-light casts weird shadows as we follow the superintendent along a narrow gallery, cut in the igneous rock to connect the vein with the shaft. At the intersection another long gallery extends to the right and left, but its parallel walls are smooth, often highly polished, at times four feet apart, again more, but always with an inclination to the vertical. These are

ON THE WAY TO A MINE.

the faces of the fissured rock between which, overhead and below, is the vein matter. Through the gloomy darkness we pick our way cautiously along the narrow plank, resting on ties laid over the gutterway. Below us, the water rushes down to the shaft, emptying into the "sump," a continuation of the shaft below the lowest level, serving as a well out of which the water is lifted by the great pumps, whose continual beat, up and down, up and down, with monotonous regularity, breaks the silence like the throb of some great hidden heart. Climbing a ladder, or rather five ladders—for there is a platform at every twenty feet—in Egyptian darkness, illumined only by the light of a candle, with ice-cold water dripping from each round and trickling along one's arm, and a small torrent from the tarpaulin hat down one's back, is apt to dampen, if not to eradicate forever, any lingering fancy for a miner's life. Arrived at this level, there is less drip and save for the rafters overhead, reaching from wall to wall, bracing the sides and supporting the broken rock above, the conditions are the same as below. Approaching the breast of the level, the silence is broken by a half-muffled chu-chu-chu, which indicates the presence of a compressed-air drill. Guided and controlled by two men, this wonderful piece of machinery accomplishes the work of ten. Attacking the face of ore, a hole is drilled from four to six feet deep, then another, and another, till the ore body is pierced by perhaps ten, which after removing the drill, are charged with powder and fired, breaking down a mass of rock weighing perhaps, twenty tons, and advancing the level several feet. Little square cars take the broken rock along the level to the shaft, whence it is lifted to the surface. Along the level at intervals of 150 feet are noticed holes up into the vein above.

Climbing into one of these we find a chamber of irregular shape, excavated by a gang of men, who break ground by drill, powder and pick over

SOME TYPICAL MINERS.

a width between the walls as wide as the ore-streak and as high as they can reach. They drive parallel with the level below, upon the roof of which they stand. The vein matter, be it remembered, is composed of "gangue," which does not pay, and ore. The miner sorts the one from the other, throwing the former behind him, and delivering the latter by shute to a car below. In these contracted spaces the miners sit or stand, doubled up and bent into shapes reminding one of the Chinese dwarfs, prepared from birth in crooked jars for the amusement of the Emperors, and pound away on the drill or peck at the dull, dingy rock. The ore is garbed in very sombre hue, a discoloration in the strips of rock only distinguishing ore from waste. The dingiest part of the exposure may contain the precious metals. There are no sparkling gems of mineral or nuggets to catch the eye. The water, standing in glistening beads on the rock, is more attractive than is the dark mass which tempts the gnomes of the mountains to brave the threatening dangers. Except for the occasional smothered boom of blasting and the click of steel, a death-like stillness prevails. The men rarely sing at their work and never whistle underground. As a class they are superstitious, and living as they do in imminent danger, have many queer beliefs, magnifying simple coincidences into causes and effect. That rats always abandon a mine just previous to an accident is held by all and the miners utterly refuse to work at a spot where a

fatal accident has occurred. Crawling up a jagged shute, over waste rock, into a stope which has been exhausted, we gaze in wonder at a pocket, empty now, but which had been robbed of $400,000 in a very short time. In a still higher level—an abandoned one—a new and strange phenomenon is met. Nature, as if to repair the destruction wrought by vandal man in her domain, has covered the decaying timbers with a soft white fungus growth, fantastic and beautiful. This is pendant from roof and walls, and is indicative of vitiated air.

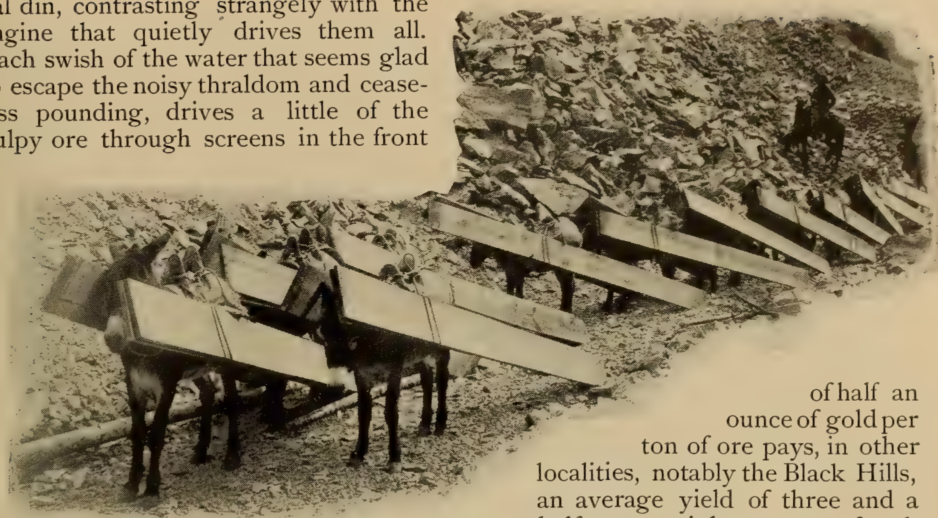
It is a relief to scramble back to the working regions and thence to the shaft, where the cage swiftly and steadily lifts its human cargo to the surface. Dripping, mud-bespattered and tallow-spotted, the visitor presents a sorry spectacle as he steps off the cage. The first sensation, on arriving at the surface, is cold, the temperature underground being much higher than even the warmest day above. A notable instance of this fact and one alone in the history of mines, is that of the Comstock mine, in which the temperature limits the depths of mining. The wall rock of this mine, on exposure to the air, decomposes, creating a heat so great that only the high wages, offered with short hours, tempt men to venture where all the tools are wrapped in cloths dipped in ice-water, and where twenty minutes is the longest period that a man can wield a pick or drill. Breathing a moisture-laden atmosphere at 150 degrees Fahrenheit and swinging a hammer is trying in the extreme, and the men are most pitiable sights as they emerge staggering, half blind, and talking incoherently. Fortunately, this condition is a rare one; but in all the mines the temperature is high.

The ore, which is the result of so much toil and planning, arrives at the surface to begin a round of varying experiences. It is broken up and the most valuable portion is culled out to be transported, crushed, sampled, perhaps washed, and subsequently smelted. Strangely enough the vendibility of the ores depends more upon the character and amount of the valueless matter than upon the actual value of the metalliferous contents, which are paid for at prices approaching New York quotations, with deductions for certain deleterious constituents and a fee for treatment. This latter charge is small for ores containing much lead or copper, which are easily reduced; but it rises with a diminishing percentage of lead or copper, until the charge for treating dry ores reaches $15 per ton. Minerals of high grade will, therefore, bear the cost of transportation and treatment at a smelter, but others require concentration before shipment.

Mills for rendering such ores marketable are situated close to the mine and contain crushers and rolls for breaking the ore; screens for sizing it, and jigs and tables for washing the valueless materials away—the former by means of a piston rapidly reciprocating in a tank, the latter with a shallow stream of water. Water is the universal agent throughout the mill and facilitates every operation, dripping from pipes, flowing in troughs through the jigs and over tables, up and down and back again, carrying pulverized rock from one machine to another and finally bearing the tailings, or waste, on into the creek, leaving the concentrates to be collected in a series of sized products containing much of the mineral within a bulk of only one-fourth the original. Fully 800 of such mills are in operation throughout the United States, and constitute very important adjuncts to mines, as all ores are more or less amenable to this form of beneficiation.

For recovering free gold from its ores the only successful method, though crude, which has attained any measure of confidence is that known as stamp milling. Imagine a long, low building, one side lined with portholes through which the rock is fed into huge mortars. In these, ranged along the wall, pestles, called stamps, drop at regular intervals, pulverizing the rock in a bath of water. One hundred and twenty-five of these stamps, weighing six cwts. each, pound away at the quartzose ore, with twenty or thirty strokes a minute, amid infer-

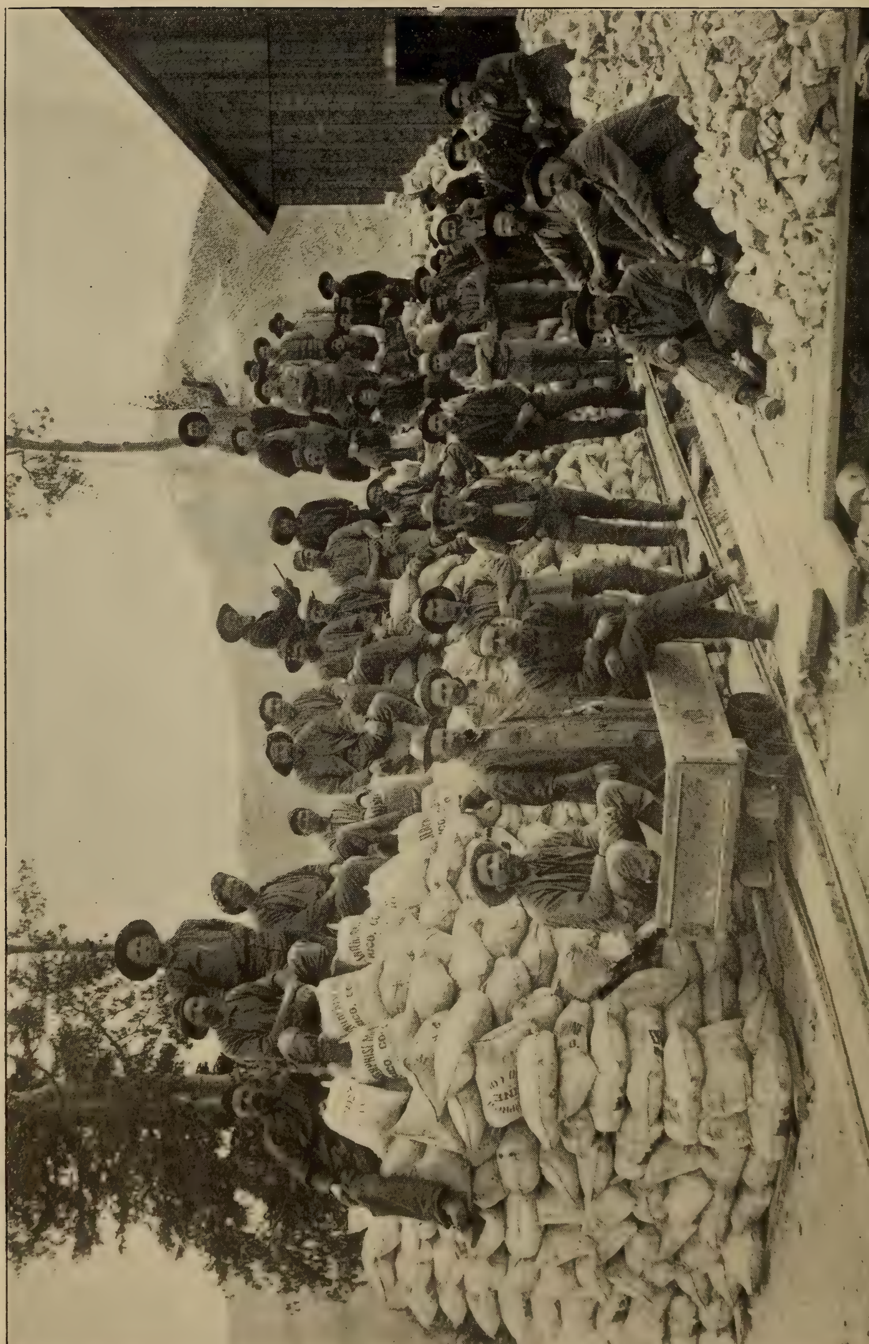
nal din, contrasting strangely with the engine that quietly drives them all. Each swish of the water that seems glad to escape the noisy thraldom and ceaseless pounding, drives a little of the pulpy ore through screens in the front



A BURRO BRIGADE.

of the mortars and over inclined copper plates, the mercurial surface of which seizes the freed gold while the rock disappears over the tailboard, onward to the creek. Formerly no effort was made to recover any value from these tailings, which still contained over fifty per cent. of the mineral. Now, however, the use of additional plates and tables adds to the total receipts, which are further increased by the introduction of blankets, in the nap of which some of the riches are mechanically collected. Though crude, this is an improvement upon the method of collecting gold in the Malay Islands, where the washings sweep over prostrate women, in whose hair the metal was caught. On every Sunday the giant pestles are hung up for rest, while the mercury gold alloy is scraped off the plates. After straining, the amalgam is of about the consistency of thick corn meal mush and contains about one-fourth of its weight in invisible particles of gold. From the results of each week's run the mercury is distilled, leaving a beautiful, porous cake of metal of the size of a base ball, as the fruits of prospecting for, mining and stamping of, perhaps, 200 tons of ore. While in isolated communities a yield of half an ounce of gold per ton of ore pays, in other localities, notably the Black Hills, an average yield of three and a half pennyweights per ton of rock warrants a large capitalization. Of the remaining processes by which ores may be treated near the mine, that of amalgamation is giving place to chlorination. The former is a modification of the ancient *patio* process ; by the use of which the nations south of us have been enabled to add $8,665,000,000 to the metallic wealth of the world. The ore is ground in peculiar native mills, by means of a flat, heavy stone revolving inside of an inclosure roughly built of stone. From this *arrastra*, the ore is deposited in basins of masonwork, fifty feet in diameter, covered with rock-salt shoveled into a flat heap or torta, into which the mercury is incorporated by the treading of a number of mules, after which the pulverized waste is washed away, leaving the amalgam behind. This is scraped from the bottom and is distilled. This primitive method was adapted to the treatment of the ores of Comstock bonanzas, by substituting iron pans for the crude masonry work, and mechanical grinders for the salivated mules. The chemicals were the same in both processes, but the yield is greater in the latter while its loss of amalgam is less.

The chlorination method is a far more curious process, and had its origin in Austria, but Yankee ingenuity devised improvements upon the "old original" which were easily carried out, and now



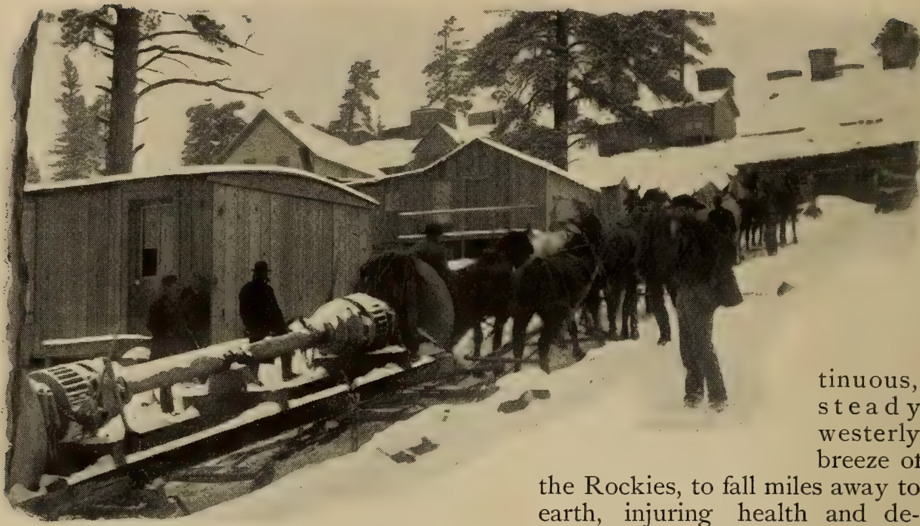
ORE IN SACKS READY FOR SHIPMENT.

the Russell process is the best mode of recovering silver from low grade ores. Finely crushed ore is delivered into slowly revolving iron cylinders, mixed with rock salt, desulphurized, and in a few hours is discharged.

The remainder of the operation is conducted in huge vats, of which there are two series, for lixiviating the ores. In one the baser metals are leached out, after which the mass is covered with a chemical solvent for the argentic riches. In time, this solution is drawn off into the lower series of tanks, where the metal is precipitated. After siphoning the liquid, the silver is gathered, filtered, and dried upon canvas, where will lie, at one time, about 95 per cent. of the original silver, the contents of a week's run—an ugly-looking gray powder which would never be suspected to have any value until a subsequent heat has expelled the combined sulphur and the silver appears in bright flakes, which are afterward melted in crucibles and cast into ingots.

These few processes and their modifications are the survivors of the many tentative efforts in metallurgical history. The miners of early days were novices and had much to learn of the methods of development and treatment. The country was remote from railroad and market; supplies and product were hauled at great expense; Indians blocked the routes of travel, impeded transportation and destroyed freight; and the purchasing power of the coin was far less than the cost of its production. But with the advent of the railroad a new era was ushered in. The prospector who had only his unaided hands and limited means with which to work was supplanted by the capitalist, with improved methods and skilled labor. The rich freight of the mountains became more accessible, and communication was established with trade centres where all the numerous operations necessary for the reduction of ore cost less than $7 per ton. The many plants built nearer to ore than to coal invariably succumbed to the inevitable fate—a shut down. "Adios. Let her rip," was the epitaph chalked on one furnace, abandoned after attempting, for three years, to compete with the central smelteries, hauling more than

PACKING COAL TO THE MINES.



HAULING MACHINERY TO THE MINES.

one ton of coal and flux uphill to melt a ton of ore, the bullion from which must retrace the steps taken by the coal.

It was twenty-one years ago that the first spike was driven on the "Baby Road" that crept out of Denver up into the mountains. Following the tortuous windings of the canyon, its tracks describing a tangle of loops and bends, over grades twice as steep and curves thrice as sharp as those of our trunk lines, this narrow gauge line was remarkable for its bold conception and daring construction. The train meandered in and out among rugged peaks, over acres of slide rock or under jutting ledges, skirting precipices, sometimes giving glimpses of green patches, brilliant with columbine, but always within sound of the rushing torrent whose eddying waters are thick with pyritiferous tailings from the stamp mills through which they have passed ; and all to traverse sparsely settled districts and offer outlet to metallic treasures. The gauge has since been widened to the standard 56½ inches, and thousands of miles of rails now connect mine and mill with furnace and mint.

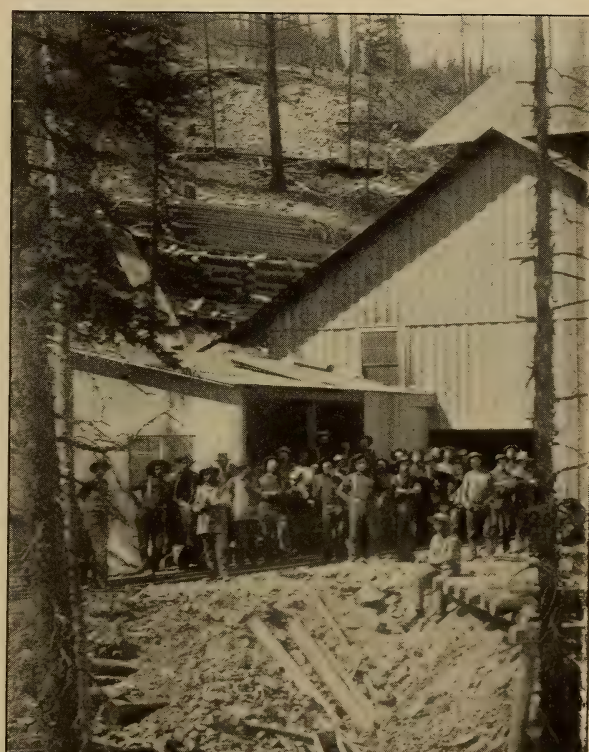
The traveler, approaching Denver or Pueblo from the east, will be surprised with the dense fumes floating on the continuous, steady westerly breeze ot the Rockies, to fall miles away to earth, injuring health and destroying vegetation with their lead-arsenic-sulphurous compounds. Day and night these gaseous streams pour forth from tall chimneys of smelting furnaces, whose hundreds of tons of solid rock are daily reduced to lead bullion or to copper matte. Neither long flues, labyrinthine chambers, nor bags succeed in totally freeing the fuel gases of the deadly fumes which are unavoidably produced.

At the works, comprising acres of long, low buildings, the clearness of the atmosphere and the neatness about the furnaces are surprising. In several buildings ore is stored. Another long building encloses under its steel roof a series of long, flat roasting furnaces. In another enclosure the different varieties of ore are separately spread, like a huge layer cake, from which are cut slices for charging into the capacious maw of blast furnaces within two-story buildings. Each roasting furnace is about 72 feet long and 12 feet wide, made of brick, strapped and tied with iron. There is a grate at one end and a chimney at the other, between which the space for its entire length and width, is lined two feet high with firebrick, its floor being divided into four steps or hearths. Fine crude ore is spread over the hearth at the cooler, and is continually stirred while the flame partially desulphurizes it. Every two hours the

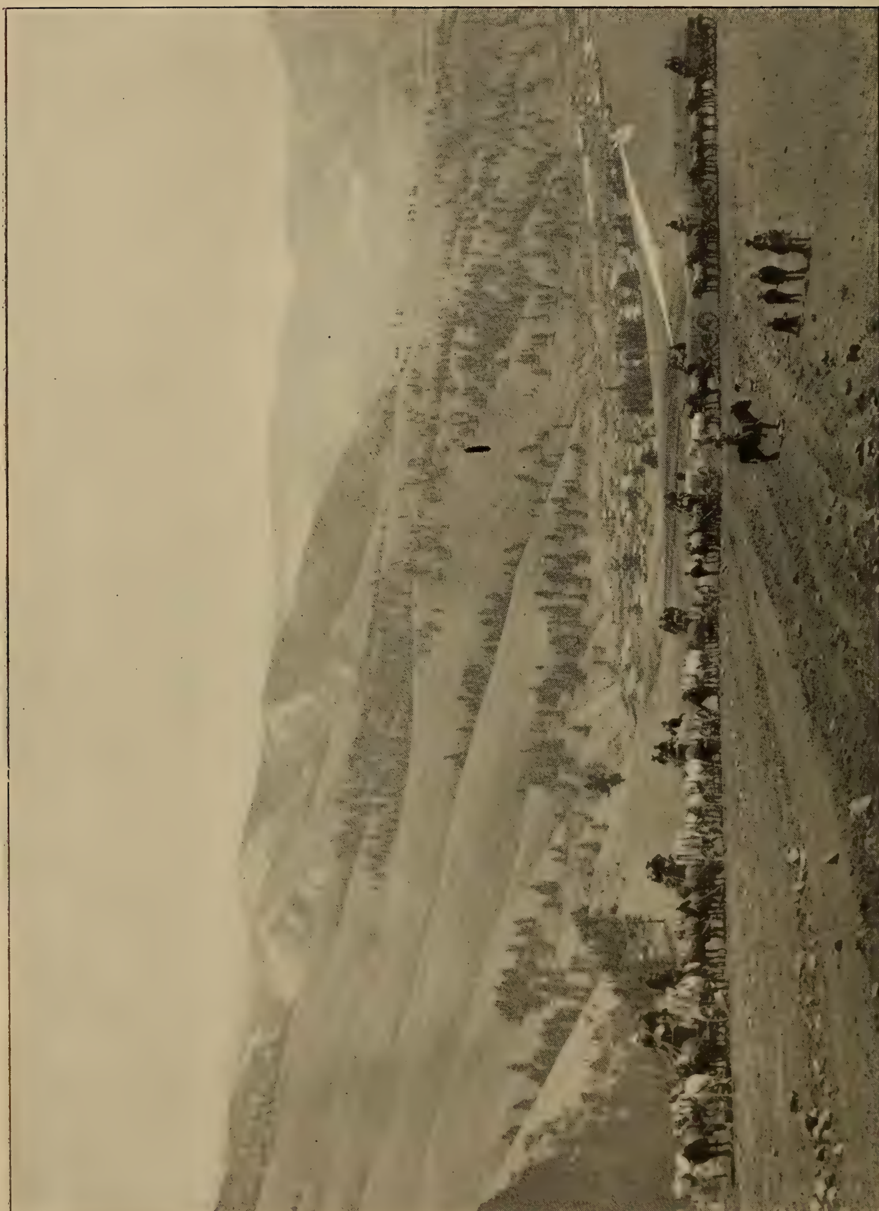
mass is moved along and dropped from one hearth to another by means of long iron shovels reaching through convenient doors on the side, following, and being followed by similar charges of fine ore. On the lowest hearth the obnoxious elements are finally removed at a cherry red heat, after which the sooty mass is withdrawn and mixed with lime, iron ore, and coke in proportions calculated to thoroughly reduce the metals. The blast furnace is an oblong-shaped chimney, 24 feet high, lined with firebrick. The lower part of its walls is made of cast-iron boxes kept cool by a continuous stream of water running through them. Looking into the open top of the furnace one would see a dark, cool mass—nothing to tell of the melting contents below, save an occasional oozing of smoke. Three separate vents are supplied for drawing off the products. From the lowest tap, an argentiferous lead bullion is received and ladeled into molds. A little higher up, a matte of copper, silver and sulphur is occasionally drawn, while four inches higher, frequent draughts of the molten dross are received into pots. The matte is treated elsewhere, while the slag is wheeled away as valueless, except for rip-raps and railroad ballast.

These operations stop not night or Sunday, but must be continuous, or else the fifty ton mass within the furnace would solidify and nothing save dynamite could loosen it. In fact, notwithstanding the ten tons of fuel in the furnace, chilling is imminent with the introduction of an excess of any fluxing substance. The appearance of the slag is watched as carefully as is any fever patient's pulse.

These operations, so quickly described, require the labor of many hands, not only of miners of ore, quarrymen at limestone, handlers of coal and stokers at coke ovens, but also one furnace laborer for every ton of ore daily reduced. A certain smeltery, of only 500 tons daily capacity, has a monthly pay-roll of $34,826, and consumes more than 100,000 tons of fuel annually. The cost of the Colorado smelting plants, aggregating 3500 tons daily, is estimated at $9,000,000. The biblical method of desilverizing the lead bullion by cupellation is not much in vogue. Instead of slowly heating the alloy upon a porous hearth in the presence of an excess of air to drive off the lead and leave behind the unaffected silver in the form of a brilliant button, it is subjected to a novel treatment. Twenty tons of bullion are melted in huge iron kettles, and zinc stirred into the mass. With its great affinity for



A SHAFT HOUSE.



ORE WAGONS GOING TO THE MINES.

the precious metals the zinc absorbs them and forms a scum that is ladeled off, robbing the lead so completely that a mere trace of silver remains. The skimmings with their 6000 precious ounces are liquated in a furnace to rid them of any adhering lead and are then distilled in pear-shaped retorts to volatilize the zinc. The remaining alloy is then poured out and cupelled, the resulting silver being melted and shipped from the refinery to the mint in bricks.

The Boston and Colorado works at Argo, near Denver, have the monopoly here of the rich copper ores which require more manipulation than lead. The roasting is performed in a similar manner, but the fusion is different. Instead of the tall blast furnace, in which the lead ore is reduced at once, the copper ore undergoes several heats in a reverberatory furnace, until the matte carries about forty per cent. of copper, thirty ounces of gold, and 1000 ounces of silver. A reverberatory is a flat, oval hearth, of about 18 x 12 feet, with a low, arched roof, lined with pure quartz brick. Four tons of ore, with a proper admixture of fluxing material, are charged every four hours and fused. The copper accumulates in a specifically heavy matte, while the slag of earthy matter floats on top. The latter is drawn off six times a day and is cast in convenient sized molds, to be thrown away while the former is tapped once every twenty-four hours. When a sufficient degree of concentration is attained, the matte is pulverized and delicately roasted on a three-story hearth, arranged like the letter **S**.

Leaving the scores of hurrying men, wheeling ore and slag, the sweltering dozens stirring the mass, the sturdy few who with hammer and drill are opening the furnace for tapping, we will visit the next building, a well guarded one, where absolute quiet reigns. Here all the fiery forces are at rest, and blue limpid waters slowly move from one to another of three series of square wooden vats. Into the upper row the roasted matte is placed and dissolved by hot water as easily as sugar is in tea. From this point the process is a singularly interesting one. The colorless solution passes quietly through the second row of vats, in which numerous copper plates are suspended ; the acid, attacking the copper, frees the silver which falls to the bottom as a pure impalpable dust. For every fifty Troy ounces of silver deposited, one avoirdupois pound of copper is dissolved. The resulting deep blue liquid passes on to the lower

LOADING CARS WITH SILVER ORE.

INTERIOR OF A SMELTER.

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INTERIOR OF AN ASSAY OFFICE.

vats, where it encounters a quantity of scrap iron which the acid attacks in turn, liberating the copper, which is thus saved and used again. The recovery of the copper requires but fifteen avoirdupois ounces of iron. Out of these tanks the solution flows to mingle with the waters of the creek. The deposited silver is shoveled into pans, dried, fused in large black lead crucibles, and molded into bricks of 1300 ounces each. The visitor is always permitted to take one of these tempting ingots—"if you can carry it." About thirty of these bricks are shipped to the mint every other day. The undissolved residues of the first row of vats are removed to a building where there is positively no admittance. It is here that, by secret process invented at Argo, the "golden fleece" is collected.

Does mining pay, is indeed a mooted question. It would seem ridiculous to ask this of an industry that has flourished for thousands of years; of one so intimately connected with the settlement and wealth of nations; of one that annually produces millions upon millions of dollars in coal, iron, lead and precious metals. And yet a wise man has said "moil not underground, for the hope of the miner is uncertain," while the many broken dreams and wasted lives bear witness that the *ignis fatuus* may lead to ruin and desolation.

Is life worth living? As it depends upon the liver, so mining depends upon the miner. It certainly will not pay if prosecuted loosely and regarded merely as a venture. It as certainly will pay, if its operations are planned and estimated with the same sagacity and precision used in other industries. Maladministration and incompetency assure failure there as elsewhere, and mining may be so conducted as to yield as small profits as any other industry can complain of. Exceedingly rich mineral is not essential to success, as witness the mining and milling of the Black-hills ores, yielding only $3.15 per ton. Great richness may be necessary to compensate for inaccessibility. Little do we realize the hardship and toil of the miner. Buried in an underground city by day, in darkness illumined by the flickering rays of a candle, surrounded by a thousand dangers, an agonizing death lurks in yawning chasms below, in loose rock overhead, pent up waters beyond and in the deadly gases liberated on every hand. A moment's delay, a careless step and his life is crushed out. It has been said that every looking glass costs a year of some doomed laborer's life. In mining for the precious metals, the

CASTING SILVER BARS.

same story is told. Each golden eagle counts for a day of suffering or for a death ; if not sudden and violent, then the lingering torture of the dread "miner's consumption."

The shortened life and weakened physical condition of many of the underground toilers are often charged to alleged dissipation, but unjustly so. As a rule, the metalliferous miner is an ambitious, honest, industrious young man. Fearless, not lawless, he is as far from the licentious habitue that Justin describes, as from the highly improbable creation of the sensational writer. Living in new and widely diversified communities, surrounded by all conceivable forms of temptation and vice, *salus populi suprema est lex* is his maxim, and vigilance committees with their quick trial, judgment and execution, seem to be necessary evils which the most law abiding citizen at times condones. Paid by the day, with no articles of agreement, the crews are ever changing, though a few remain faithful. When the mine is not close to a town, the company "bunks" the men in fairly comfortable quarters. There the cook is the autocrat, drawing a salary of from $80 to $100 per month, and is responsible to no man. As may be imagined, life at one of these isolated mines is prosaic and uneventful to the last degree. The favorite amusement is gambling, as on ship-board, even the most trifling incident being utilized. Many a time have I seen a number of stalwart fellows seated about a table, each gazing intently at a lump of sugar before him. The winner of the stakes in the centre of the table, is he upon whose sugar a fly first alights.

THE CHALK AGE OF MECHANICAL ENGINEERING.

By J. F. Holloway, Past President Am. Soc. M. E.

IT was said of a celebrated temperance lecturer, that his success was largely due to the fact that in his travels about the country, he had with him a man whose whole life had been spent in the indulgence of habits just the reverse of those he advocated, and who by thus doing the things he ought not to have done, and leaving undone the things he ought to have done, became to be and indeed was exhibited as a "*frightful example.*" I speak to those to-day whose good fortune it is to have been born at a time when it is possible to avail themselves of the advantages of college education, of study in technical institutes, and of practice in schools of manual training. In addition to the aid of teachers, the surroundings of libraries, laboratories and workshops, you have the privilege of listening to lectures given by cultured men renowned in science and art.

As a background to this bright scene, it was needed that there should come before you one who, never having had any of these opportunities, one who wanting in those graces and accomplishments that come or should come from a collegiate training, and who should be in fact a "frightful example" of those whose knowledge at best is more of the practical than of the theoretical kind.

Now, do not let us start out with a misunderstanding between us. Do not for a moment believe that I undervalue education, be it acquired where or how it may be. I have all my life felt the need of it, and have always known how much it would have helped me, had I been privileged, as you are, to find in such surroundings such valuable aid as you must. And yet, are there not some compensations which serve to even up all our lives? The dweller amid the hills, whose rough pathway lies onward and upward, ever surrounded by difficulties and dangers, as he climbs and toils, he is by a beneficent Creator endowed with a will to dare and with a strength to accomplish that which a dweller on the plain has no need for, and does not possess.

It is said there is no royal road to learning, and perhaps there never will be one, but the road over which the young man desiring to become an engineer travels to-day is a far plainer and easier one than the one over which his predecessors struggled and stumbled. It has been well said of the present age that, so far as it concerns engineering, at least, it might well be called the "blue print age." The age of which I speak might equally well be called the "chalk age." In other words, it will be my mission at this time to speak to you of the old time millwright, machinist and engineer as I remember them at the time when I first began to learn something of the art of working iron. I trust the picture I may present will not be without interest and some benefit to you. It will be the picture of a gone-by age, a picture of scenes you will never look upon except in imagination.

As I have walked through your well appointed workshops, your well lighted and convenient drawing rooms, have looked into your well supplied libraries and laboratory, have listened to the instruction given by teachers and lecturers each skilled in some particular science or process, there has come back to me the memory as to what

Mr. Holloway's interesting talk on "The Chalk Age of Mechanical Engineering" first appeared in the shape of an address delivered at Sibley College, Cornell University, several years ago, and subsequently elicited many commendations from engineers in different parts of the country whose early experience had been so admirably reflected by it. The lapse of time has, if anything, added to its interest; hence its reappearance here.—THE EDITOR.

were the surroundings, what the opportunities, of young men who, starting at the time of which I have spoken of, had the same aims and ambitions as have the young men before me now. We will lay the scene I am to describe in some remote inland village, beside some rapid running stream, whose swift waters afford the power used for turning wheels which as yet had not been harnessed to the then newly talked of, but as yet not much used, steam engine.

Our hero will be a country boy who early began to show signs of ingenuity and a taste for mechanical pursuits. As usual, his first attempt in engineering begins in whittling a pine windmill, which is tacked on the ridge pole of his father's barn, where it serves to show not only the direction of the wind and its force, but as well the bent of his thoughts and desires. Next we find that he has built across the brook that flows near by a dam, whose pent-up waters turn the wheels he has built in imitation of those he has so often watched at the saw mill. Later on, a rudely built pump, actuated by the water-wheel, adds a new triumph to his skill, as it flings its tiny stream up into the sunlight.

This may seem a crude and unpropitious beginning in the study of so grand a science as is engineering, but I venture to say there are eminent engineers living whose well planned and ponderous engines are the admiration of all who behold them, who in the well earned success of their later years find no such joy as came to them long ago, when, as barefooted boys, sitting in the sunshine of early spring, on the side of the brook, nursing their knees under their chin, they watched with throbbing heart their little wheels go round, and planned and yearned for further and greater triumphs. Borrowing of the carpenter an auger and a drawing knife, and finding in the wood shed a hatchet and a saw, in winter he makes his own sleds, in summer his wagons ; and while their design may be faulty, their workmanship rough, the ingenuity shown by which unsuited things are made to perform needed results show a study of the situation truly commendable.

Sandwiched into the years as they go by are more or less of school days, in which the branches of a common education are learned. In the course of time there came to be held a family council, the subject of which is our boy ; and where, in spite of what may have been the hopes, desires and ambitions of the other members of the family concerning him, all agree that it will be useless to try to make of him a doctor, lawyer, merchant or minister, as he is evidently bound to be a machinist and an engineer. So plans are made by which he is to have a place as an apprentice in the only foundry and machine shop the village affords. Having heard something of the steam engine, and having read of its having been used to drive mills and boats, our hero dreams of the time coming when he can handle a steam engine, to start and stop it at will.

To the poet there come dreams of some fair Arcadia, some paradise regained, some spot where glowing colors greet the enraptured sight, where the fragrance of flowers loads the air with perfume, and where sweet melodies charm the listener into raptures of repose. The navigator has in his mind's eye undiscovered isles whose beauty and solitude woo him onward. The adventurous miner, worn and weary, lies himself down to sleep amid the rugged canons of the far West, and in his dreams there opens in the ragged and seamed rocks that tower above him hidden veins of untold treasure ; but to the boy of long ago, who worked and wished to be an engineer, there came no dreams more delightful, no hopes more pleasing, than of that day when he should hold beneath his grasp to start, to check, or to command some ponderous engine or grand machine. Deem it not idle to thus dream, and hope, and speculate of the future, for had not our hero had some such visions to cheer him on, he would oft have been far more discouraged than he was, as he stumbled and tripped along the

rough road he had chosen to walk in. We next find him at the open door of the village foundry, where he is met by the boss, who, taking him into a little den behind the cupola, gives him a stump of a broken file, and shows him how to rub off the sand from the newly made castings. To his kit of tools there soon is added a lump of a hammer and a stump of a chisel. With these he is further taught how to chip off the bunches and ragged edges the unskillful molder had made, and the runners and gates he had left on. To those who have done this for the first time I need not say that many, far too many of the lumpy hammer blows missed the stumpy chisel, but did not miss the tender hand that held it. It was at such times that the pain of self-inflicted blows, added to the cheerless surroundings, made our apprentice boy to almost wish that he had chosen to be a minister instead, but a glimpse, even through tears, of that glorious vision of the future made him to clinch his teeth together, wrap a rag around the bruised and bleeding hand, and try it again. After awhile some kind-hearted journeyman, seeing his bleeding hand and remembering his own beginning, tells him to go up in the pattern shop and put some shellac varnish on it, which he does, and afterward goes about with a feeling that if he has not yet learned the trade, he has at least learned a new wrinkle. After awhile he is promoted to help wheel scrap and pig iron up the runway to the charging floor of the cupola ; and on days when the heat promises to be extra heavy, he helps the melter charge the coke and iron into the cupola, and to chalk their weight on the tally board above the scales as they go in.

Later on he makes friends with the molder, by riddling his sand for him or by clay-washing his "gagers," and he thus gets some insight into the art of filling and ramming sand in a flask. At noontime he gets a little flask in the corner, and tries to make a mold of some fancy piece of ironmongery. In my time the favorite pattern, the *piece de resistance*, was a flat-iron holder ; it took but little iron to make, had an ornamental look, and was easily carried home as a trophy.

Here he works away by himself, copying, as he thinks, all the operations of the molder, and when the flasks are being poured off, he importunes his friend the molder to pour his flask also ; which he does with a quiet smile, the meaning whereof was at the time unknown. Our embryo molder and engineer can scarcely wait for the gate to solidify, so impatient is he to see the result of his labor ; but, when he lifts off the cope, he finds beneath the mold all right, but no iron in it—he had forgotten to cut a runner from the gate to the mold, by which to let the iron flow into it. His friend the molder well knew that he had neglected to do so, but he thought the best way to have him remember to do it afterward was to let him make a failure of his first attempt.

It may seem a strange thing that a boy wishing to be a machinist and an engineer should begin in the foundry, but so it was in the "chalk age" of which I speak. After working about the foundry until he could mold grate bars, sleigh shoes, and plow points, and until another new boy had come to take his place in cleaning castings, he was promoted to striking in the blacksmith shop. Of the misfortunes that befell him there, while learning the art of working wrought-iron, I could fill far more time than is now at my disposal.

As you will never again see the old time apprentice boy, who wanted to be a mechanical engineer, so no more will you ever see the old time smith shop, in which he passed a considerable portion of his time, and through which he traveled on this, as he then thought, by no means royal road to learning. No swiftly revolving fan made "music in the air" in that shop ; but instead, a wheezing bellows, whose wrinkled leathern sides puffed out and shrunk in with every stroke of the bellows pole, gave breath to the flame upon the hearth. When an extra heavy heat was to be made, or a weld taken, a heavy stone was laid upon its floating

top, which added fierceness to the blast, and labor to the sweating youth at the pole. The art with which the skilled smith heaps high the coals above the tuyere, sprinkling their outer surface with water in order to make beneath it a hollow fire whose blazing roof should reflect down on to the iron beneath the inclosed heat should be seen, not told. His watchful eye peers into each crevice, to see to it that the heat is made uniform, and that no burning of exposed edges takes place. Now and then he dashes in a little clean sand to make a flux that shall protect from oxidation its more exposed parts.

Ranged in front of the anvil are the three or four extra strikers called in for the occasion, and who, with upraised sledges poised in the air, await the coming heat. Now from out the roaring fire the white hot iron comes, dripping with melted slag, and about which there gleams up a halo of fiery scintillations that lights up the dingy shop with an unwonted cheerfulness. "Now," cries the smith, and the leading sledge falls on the plastic iron, followed one after another by the others, until under the tuneful measure of their falling strokes the yielding metal is slowly and steadily beaten into forms of usefulness and beauty.

Here, as in the foundry, our hero is adding to his stock of useful information. Watching his opportunity, he tries his skill in shaping a piece of iron, and with the usual experience of all who first essay that apparently simple operation, he finds that every time he lays the heated iron upon the anvil, and hits it with the hammer, it somehow twists from out the tongs, flies past his head, and lands across the shop. Yet every time he starts out to hunt up that lively iron, there comes to him an idea that perhaps he had failed to hold it level on the anvil, until, with frequent dodging and frequent chasing, he finds that the apparently easy thing of holding a piece of iron in a pair of tongs while pounding it, is an art. Soon he learns how to heat and shape a steel cold chisel, and much delight it is, when finished, to heat and dip it in the water, rub it bright with a bit of sandstone, and watch with nervous anxiety the glowing colors of each varying temper, as they chase each other toward their vanishing point. If in his haste he plunges the steel back into the water too soon, and leaves it so hard that it breaks, or if he neglects the cooling too long, and his chisel is made soft and worthless, with each failure there comes to him, and to remain with him, an education which practice alone can bring, and practice alone perfect.

The drawings furnished the smith in those days were of varied styles. Sometimes the object wanted was somewhat crudely drawn in the dirt floor of the shop, by the toe of the master's boot. If it was something *very* particular, it was chalked out on the back of the door or on the top of the bellows, accompanied with a verbal description, aided by a thick thumb sliding up and down a well worn rule.

Having glanced at some of the knowledge and experience that came to our hero through the foundry and smith shop, all of which he found of great value in after life, we must hasten on to the senior years of his study, which finally culminated in his graduation from the machine shop. I have, in a hurried and imperfect manner, tried to describe the foundry and the smith shop of the "chalk age," but how shall I be able to bring to your view the machine shop of that gone-by period—a shop which I so well remember, but which you will never see? As I walk through the steam heated, electric lighted, frescoed and varnished machine shop of to-day, whose swept and garnished floor gives no hint of litter or of labor, I have to pause and close my eyes until memory brings back the picture of the low, dingy, ill-lighted, worse heated, and scantily furnished machine shop of the "chalk age" and of my youth—shops then to be found all over the country, but gone now and forgotten; shops in which the boys of long ago worked, and unaided, wrestled with difficult problems, and from out of

which there came some of the ablest thinkers as well as the most successful engineers of to-day. Were I speaking to the older members of a profession of which you are standing on the threshold, I could, I am sure, even with my imperfect description, recall to them memories of this gone-by, but not forgotten, epoch of their lives.

I need not describe to you the changes that have come to the exterior of the modern machine shop ; you see them everywhere with their storied walls rising high in the air, with railway tracks running beside them into well arranged yards, where giant cranes lift with outstretched arms ponderous beams and bed plates, finely finished engines, and other massive machinery with celerity and ease. If you do but look closely, you see also the little lawn beside the door, where in the early springtime budding blossoms grace its border ; and in the summer nodding rose bushes add beauty to the scene and a pleasing odor to the air. It was not thus in the "chalk age." Accustomed as are those before me to see and to use the elegant and burnished machine tools of to-day, in which each curve in the leg has been the study of an artist, each screw and bolt modeled after the most approved scientific formula, where the cross-feeds, the disengaging gears, the stop, as well as the go-ahead motions, have been by one maker taken from another, and altered and changed beyond the recognition of its author, until, like the bones of the pauper, it is something "nobody owns."

I can perhaps convey some idea of what the old time machine shop had by naming some of the many things it did not have. While it did have, as you will infer, a foundry at one end and a smith shop at the other, and between them little else than smoke and grit, fortunately the latter got so well ground into the apprentice boys of those days that it stuck to them all their lives and served to help them out of many a difficulty. There were no planers there, no slotters or shapers, no boring mills ; and all we boys knew of their existence were tales told us by bibulous tramp machinists, who, wandering out into the then far West, filled us with wonder as we sat about the stove at noontime, and listened to the tales they told of the big tools they had worked on at Matty Baldwin's, in the Allaire, the Secor, or Novelty works, or at West Point. But not alone were all these wanting in the old time shop, but as well were twist drills, except of the home made pattern, screw cutting machines, relieved taps, etc., while jigs, standard gauges and reamers were either among the things not yet dreamed of or among those only hinted at as being possible in the far off machine shops of the millennium.

There was there, to be sure, the wabbling grindstone in the corner, above which hung the white lead keg, emptied of its paint, but filled with water which dripped on the revolving stone, graduated as to the quantity escaping by a loosely fitted pine plug in the bottom. In the centre of the shop stood the cannon stove, about which was heaped up fortifications of ashes, coal dust and shop litter, and around which the cub machinist, petticoat lamp in hand, skirmished at night, stumbling, and barking his shins against the broken horse-power machines and corn shellers that lay in ambush for him in the darkness.

Those of you who have chosen mechanical engineering as a profession, and who are to devise and direct the vast engineering plants of the future, will never have among your experience anything akin to what all the older members of the profession have had, of the upright drill of the "chalk age." You will never enjoy the luxury of hanging on the outer end of a scantling, the other end of which was under a beam, or the vise bench, and where between you and the beam a journeyman machinist, sitting on the floor with an iron brace and a flat drill, calmly and leisurely bored holes in a fire front or mended a broken casting. When I said calmly, I meant calmly so long as the cub held the lever steadily, and the flat drill found no blow hole in the casting into which to drop in and stick

fast; for when this happened, the plate would slip out from under the scantling, the wimble, the lever, and the cub usually came down together in a pile on top of the prostrate journeyman, who, scrambling from out the wreck, and alternately nursing a jammed finger and rubbing a bruised leg, added brilliancy to the tableau with the blue light of his profanity.

Neither will any of you ever enjoy the pleasure of being sent down with the workmen some bitter cold winter morning, into the wheel house, to help chop out the old pitch-back water-wheel which the night before had locked its icy arms with the forebay. Neither, after this has been accomplished, will you have a distinct remembrance how, for days afterward, the old wheel would revolve with diminishing speed, until shafts, and wheels, and pulleys, all through the shop, would almost come to a standstill, until the ice-loaded side of the wheel had passed the top of its revolution, and then with gathering motion for a few moments everything would fairly buzz with unwonted speed as the loaded side goes down.

I am sure that no graduate of Sibley College will ever have any experience in cutting bolts and tapping nuts with the appliances of this gone-by age. As I before said, there were no bolt cutting and nut tapping machines in the old time shops of which I speak, and I never look upon one of these elegant and polished thread cutting machines, in which the severest labor of the attendant consists in lifting the bolt up on the machine, and gently turning a lever to clamp it in its jaws, and then push it forward until it comes in contact with the well shaped dies, which, under a stream of self-pumped oil, cut on it a clean, smooth, and uniform sized thread, and which when finished is dropped into the sawdust bath below, but that I am reminded of the well named "jam plate" of my youth, and the flat sided taper taps that kept it company.

The rule of the smith was to swage down the end of the bolt until it would enter the nut, and the barbarous screw jamming tools, aided by the strained muscles and the sweating brows of the apprentice boys, bruised and raised up a thread outside the bolt, and inside the nut, so they would fit together. So uneven were their sizes, that each bolt and nut were fitted to each other, and when taking down a machine, woe betide the fellow who got them mixed!

I find that my time will not permit a description of all the tools of the old machine shop, few and crude as they were. The old bull lathe, with the wooden shears (iron strapped) and the slide rest, and hand turning tools that belonged to it, have either been changed beyond recognition or buried under the scrap heap of the past. Neither can I describe even a few of the innumerable contrivances we were compelled to make in order that our scant tools could be made to do work which the new and improved tools of to-day would make nothing of doing. But all this had its value. When every day brought a new necessity, each day as well brought a new device for its accomplishment, until the machinist who learned his trade in those days, and in shops that had but few tools, had resources of experience and of expedients that gave him courage to attempt almost anything. It is a great pity that there has not been preserved, by means of cuts and drawings, some of these exceedingly ingenious makeshifts in the way of impromptu boring machines, facing off tools, drilling apparatus, and screw cutting attachments on engine lathes, etc. Many of them were curiosities in which odd wheels picked out of the scrap heap, joined with jiggers of all kinds and shapes, tied with clamps and long bolts made to do service as short ones, by having strung on them as washers a lot of worn out nuts, the whole turned with a crank by hand, or by a rope, which, turning several corners, reaches somewhere a revolving pulley for the required power.

New and improved tools have done away for the necessity of such contrivances and they have also done away, I fear, with the skill and ingenuity then

required in the workman. There were giants in those days, in the way of workmen, who with only a hammer, a chisel, and a file, could fit up in elegant style the strap joints and connecting rods which to-day come finished and polished from the machine tools without the aid of either. These were the days when the ways of lathes were chipped and filed, as were the guides for steam engines, and indeed, all plain or dressed parts of machines.

I have not thus rehearsed the story of the "chalk age" simply to tell you what pluck, energy, and untiring industry then accomplished, but to give you an idea of the superior advantages you who are now before me, and who are seeking to become skilled in the mechanic arts, possess over those who have traveled over this road before you. If, with the same high aims, the same undaunted courage, you start on this journey, aided as you are by all these fortunate surroundings, there will be no reason why the coming engineers may not at the last lay down their work with the same feeling of satisfaction as do the engineers of the present as they look back on what has been accomplished in the half century just passed. And need I say that if the world's progress is to be aided by a corresponding epoch of great inventions, if it is to have its civilization, its commerce, its industrial pursuits, as well as its education and the general welfare of all, advanced with the same steady, onward march in the years that are to come as it has had in the years that have gone, it will be to the engineers which the technical institutes, the manual training schools, are to furnish, we must look for its accomplishment.

If you are inclined to think lightly of the task that is before you, if you are inclined to think disparagingly of the artisans and engineers of the past, and of what they have done, just for a moment think of what has been accomplished by them in the fifty years or so just gone. Of course, you cannot remember the time when there were no railroads, no locomotives, no steamships, no telegraph wires on land or cables under the sea, or scarce of the time when the telephone had no existence, except in the imagination of Shakespeare when he spoke "of airy sounds, that syllable men's names." You can scarce conceive of the time when there were not, as there now are, immense manufacturing establishments all over this land, in which everything, from the most delicate screw within your watch to the most ponderous engine, is turned out by machinery. For a description of the time in which all these things were unknown, you have not to listen to the "tales of a grandfather." Your father's remembrance will serve as well to enlighten you.

The world will never know, for it will never stop to consider, how much it owes to the inventor, the artisan, and the engineer of the past. While some of them lie in honored sepulchres and their memory is revered, vast numbers of them lie buried in unknown graves. Many sleep their last sleep in the village graveyard on the hill which overlooks the scene of their life's struggles. Some yet live, leading quiet, plodding lives, who in one way or another, by their genius, their industry, and perseverance, have done much to bring about the wonderful changes of which I speak. Here and there, as managers of vast iron and steel works, mines, and manufactories, which their genius created, may be seen moving about quiet, thoughtful men, who, were they not pointed out to you, you would never dream were the originators of the vast industries they control.

In many instances most marvelous changes have taken place within your remembrance. There are places now busy with the hum of industry, whose towering chimneys blacken the air with their belching clouds of smoke, where the clamor of clashing wheels and shrieking whistles fill the air with strange sounds, and where the measured beat of immense steam hammers make all about to tremble; places where before a hundred fiery furnaces relays of swarthy workmen move to and fro, charging into their hot mouths or drawing from their fiery throats huge

ingots of iron or steel, conveying them to gaping shears whose iron jaws bite them asunder, or to remorseless rolls which mash and mold them through unyielding grooves, and from out which the hissing, tortured metal writhes and twists like some great reptile in agony. If you do but follow the metal as it is drawn back and forward, pushed here and there, turned over and about as it would seem by unseen hands, helpless and as yielding as the clay in the hands of the potter, you will soon find it resting on its hot bed, a finished rail that shall bear upon its upturned head the traffic of the nation. And all this shall be upon what was, within your memory, a green meadow, beside which there flowed a placid river, and where the most energetic action within one's vision was the slowly moving yoke of oxen which on the hill side beyond leisurely dragged a plow ; or the boy, sitting on the projecting trunk of a dead tree, watching with patience the too restful floating cork which even the passing breeze was too gentle to disturb with a rippling wave.

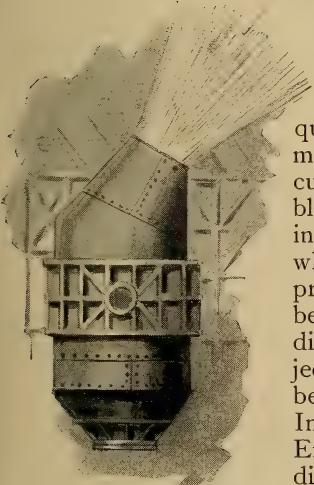
I can point you places where, but a few years ago, naught was to be seen but a worn-out cotton plantation, with here and there a tumble-down log cabin without doors or windows, ornamented at one end by a jagged stick chimney, and at the other with a coon skin stretched out to dry ; and where the oldest and almost only inhabitant might have been seen sitting on the top rail of a worm-eaten fence, smoking leisurely a cob pipe, watching the while with half closed eye the lazy, floating buzzard that circles in the sky above him.

Go there to-day, and note the changes that have come over the scene. Over lines of steel which reach from the storm-tossed waves of Erie to where the dull swash of the waters of the Gulf die away amid the lagoons of the South, from the sands washed by the Atlantic to the rocks of the Rockies, cars freighted with the product of many climes pass to and fro. From beneath the soil once plowed by the slave there now comes to the sunlight thousands of tons of coal to feed fires that go not out by day or by night, that give breath to panting engines, which in turn set aglow vast furnaces that light up the midnight hours so recently devoted to silence and to solitude. Along the vanishing furrows the plowman had left, lines of street cars are to be seen ; on all sides, mills and manufactories give a hum of industry all unknown before. Churches, school houses, and costly dwellings have sprung up like magic amid the stubble fields of the past, and over the scene where ignorance and indolence so lately held undisputed sway, manufactures have bred commerce, and busy, whirling wheels have quickened the life blood of trade, until through every artery and vein it pulsates and flows with a force and vigor never before known beneath a Southern sun. What has brought about this change? Who was it that waved above this hopeless spot the magic wand that woke it into life, and thrilled it into impulsive energy ? Need I tell you it was the engineers, and largely so the mechanical engineers ? Who are the mechanical engineers of our country ? They are men seldom seen on any platform, men who are seldom heard in any public assembly, and whose names adorn no printed page. They are men whose lives have been spent amid the rumble of whirring wheels, the roar of flaming furnaces, the hum of spindles, and the click of flying shuttles. Among them are many whose forms have grown bent by labor at the bench or the lathe, whose eyes have grown dim by the feeble light of the workman's lamp, whose gray hairs and worn looks speak of hours of toil and nights of restless tossing, as they studied and dreamed on some then unsolved problem which, worked out later, has benefited all the world. They it is who have invented, worked out, and brought to their present state of perfection the steam engines as shown in the locomotive, the steamship, and the mill. They have devised and built the tools and machines that have made comforts possible in the poorest homes, luxuries in the richest. Their

labors and their lives have advanced civilization, education, and all good things that have lifted the world up higher, made it more comfortable, more enjoyable, and better suited for the happiness of all in it; and I feel that I would not have done my duty at this time to them and their memory, did I not say all honor to the mechanical engineers of the "chalk age."

CONSOLIDATING STEEL INGOTS.

By J. L. Sebenius.



EVERY steel manufacturer is well acquainted with the many and great difficulties caused by blow-holes in steel ingots, especially when it is desired to produce steel of the best quality. In discussing the subject a short time ago before the American Institute of Mining Engineers, the author directed attention, among other things, to the well known fact that the number and size of the blowholes in the ingots increase, as the amounts of phosphorus, sulphur, manganese and silicon decrease. For instance, a steel rich in silicon may give a fairly good ingot, although a number of blowholes may be present in that case also, while a steel fit for the manufacture of tools, etc., gives an ingot which, when broken open, presents the appearance of a sponge.

In hammering and rolling the steel, these blowholes of course are contracted, their walls are pressed together and at first glance the bar or rail appears to be perfectly sound and homogeneous. A closer examination, however, reveals that this is not the case, but that through the rolling and stretching, the walls of the blowholes have been brought in closer proximity to each other, but without any joining whatever, and thus the result of the stretching process is only that the holes have been pressed out and the enclosed gases have been compressed.

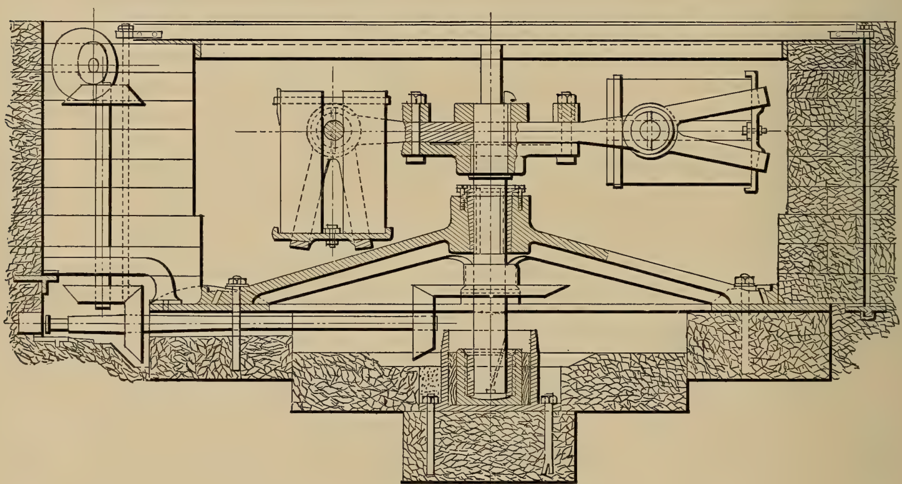
During the many years that the author has been engaged in the manufacture of steel he has tried many different ways and means to prevent the forming of blowholes, and by using silicon and aluminium he has partly succeeded. But what has been gained as to the density of the material has been lost in its purity and quality. Furthermore, by adding silicon and aluminium, it is not possible to rid the steel of the large amount of gases absorbed by it in its fluid state. These gases are merely distributed, and the result is a large number of very small blowholes throughout the ingot. Only during the last few years has the author been able to overcome all difficulties, and to get rid of the gases without adding any detrimental substances, and is now able to produce steel ingots, perfectly sound and of superior quality.

This result was first reached after the author conceived the idea of bringing the liquid steel, directly at the close of casting, under the influence of centrifugal force. As the steel gradually solidifies the gases, which heretofore have been dissolved in it, are liberated. If force, or only an insufficient force, is acting upon the steel, these gases remain inclosed in the ingot, forming bubbles or blowholes; but if, on the contrary, an adequate centrifugal force is acting on the metal, they are forced to leave their position and move toward the centre of rotation. The next step

was to construct an apparatus by means of which the melted steel could be brought under the influence of centrifugal force. The work performed by this apparatus is such as to give entire satisfaction. As far as simplicity of construction, strength and durability is concerned, nothing more can be expected. Two of these rotators are now in operation in Sweden, and several are now under construction in other countries.

The machine is shown in the accompanying drawing. It consists of a horizontal yoke, attached firmly to a vertical shaft. The yoke itself is composed of arms set radially at right angles to each other, and to the end of each is fastened, by means of a pivot, a strong steel trap, movable in the vertical plane around the pivot. In this trap the molds are placed. When the apparatus is set in rotation, the trap and the molds, with an increasing speed, deviate from the vertical position, until finally, when full speed is attained, the molds have taken up a radial position with the open ends turned toward the centre of rotation. When the machine is brought to rest, the molds again take up their former vertical position.

The liquid steel is poured into the molds above referred to from one or two ladles, so constructed as to fill four molds at once, thus avoiding unnecessary loss of time. The fluidity of the liquid steel is an important factor in attaining the desired results. As soon as the molds are filled, the rotator is set in operation, and a speed of about 120 revolutions per minute is maintained until the steel in the mold is solidified. During the whole time of rotation, gases are seen to escape from the open ends of the molds, and when they cease to do so it is known that the steel has taken up the solid state. For ingots about fifteen inches square, the solidification will require about ten minutes, and for every ton treated in this way about five to six horse-power will be required. A model, on $\frac{1}{10}$ scale, of such a machine, constructed for 15 ton charges, also specimens of the "centrifugaled" ingots, were exhibited in the Swedish building at the Columbian Exposition.



MACHINE FOR CONSOLIDATING STEEL IGNOTS.

If Bessemer or open-hearth steel is "centrifugaled," the resulting quality is the same as that of ordinary crucible steel of the same chemical composition. This can readily be explained. The crucible cannot change the steel in any other way than by making it denser, and thus, the ingots sounder; and, if this soundness can be effected by other means, crucible and "centrifugaled" steel of the same chemical composition

must show the same physical qualities. In steel of a high percentage of carbon, the ingots, as generally made, show an inner core clearly harder or higher in carbon than the rest of the ingot, which feature, of course, is very objectionable. The "centrifugaled" steel does not show this defect. The physical and chemical conditions are the same throughout the entire ingot. Here, however, it must be observed that steel of high percentage of carbon shows, on the upper surface of such a "centrifugaled" ingot, a light skin, a fraction of an inch in thickness, which proves to be somewhat harder than the rest of the ingot. This fact the author should explain in the following manner:

When, in an ordinary ingot, the liquid steel is solidifying, this action commences at the outer edge of the ingot and, proceeding inward, particles of carbon refuse, if one may use such an expression, to unite with the solidifying mass of steel, and these particles, in the form of carbon, or, it may be, a carbide of iron, work their way toward the liquid centre of the ingot, where they are ultimately captured by the final solidification of the entire mass of steel. In "centrifugaling," on the other hand, these particles, whether carbon or carbide, on account of the centrifugal force, and their lighter specific gravity, are forced out of the liquid steel, and, as they can hardly be expected to disappear, as the gases do, they naturally must be somewhere in the ingot, and they are, in fact, found in the very edge of the upper end. Here, however, they do no harm, since some small part of the end of the rolled out ingot has to be sacrificed anyhow, on account of the "piping." When this small part has been cut off, every rod, bar, rail, or plate, manufactured from "centrifugaled" steel is perfectly homogeneous, and shows throughout exactly the same chemical qualities.

The drawing, and also the model exhibited in the Exposition, showed a simple, durable, and inexpensive machine. Once built, it requires but little attendance. Through this method the following advantages have been secured: 1. Ingots are obtained free from blowholes and sound, without adding any detrimental substances whatever. 2. The amount of carbon in the steel is evenly distributed throughout the whole ingot. 3. The piping is reduced about 60 per cent. 4. The amount of fuel used in the heating furnaces is lessened, for the reason that, as there are no blowholes, no welding-heat is needed, and, for the same reason, time is saved, and also the material that would be lost through oxidation in a more intense heat. All the heat the ingot requires is only what is needed to make it pliable for the rolling mill. 5. The steel, after being "centrifugaled," shows all the physical qualities of a crucible steel of the same chemical composition.

SOME HEAVY MODERN PUMPING MACHINERY.

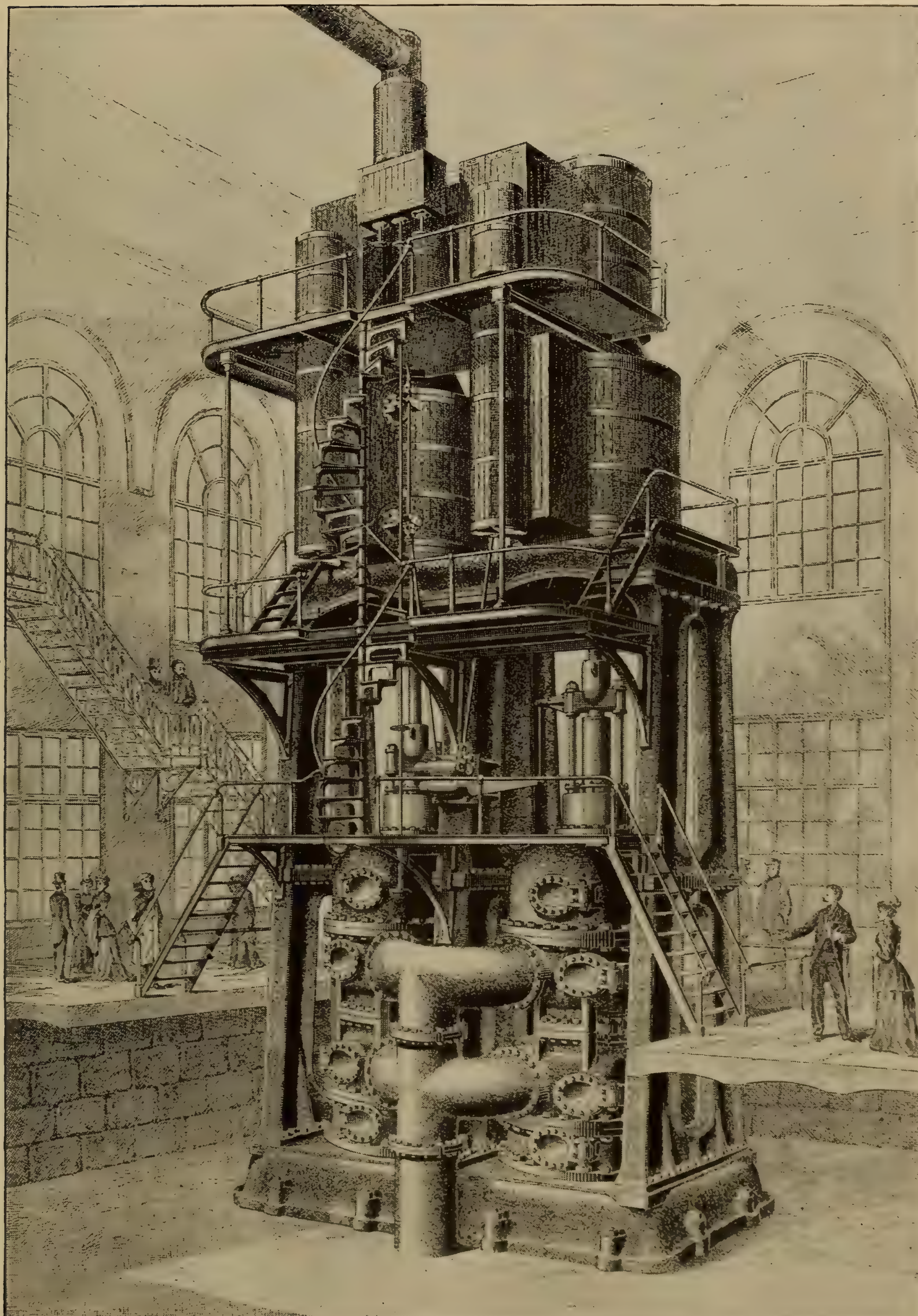
By Geo. L. Clark.

RAISING WATER IN EGYPT.

IN a paper read before the American Water-works Association at one of its recent annual meetings, Mr. T. W. Yardley portrayed in a very interesting manner substantially what the position of the pumping engine was a few hundred years ago. The first "lifting pump," for example, he said was invented in 1425, but was limited in use until 1581, when one Peter Morice was given a grant from the Lord Mayor and Commonalty of the City of London for the term of 500 years for the supplying and conveyance of water into houses by pipes from an artificial forcer from the London Bridge, on condition that the said Peter Morice should pay ten shillings annually into the Chamber of London; and he was authorized to erect an engine within the first arch of the London Bridge for that purpose. As this device completely effected the object, another grant was given by the same authorities for the use of another arch in the bridge.

According to Mr. Yardley, a description published in 1633 says: "The present supply of good water for London is like to be very much enlarged by the great improvement of the waterworks of Peter Morice, before mentioned, who, being a Dutchman, in the twenty-third year of Queen Elizabeth, first gave assurance of his skill in raising the Thames water so high as should supply the upper parts of London; for the Mayor and Aldermen came down to observe the experiment, and they saw him throw water over St. Magnus' steeple, before which time no such thing was known in England as the raising of water." His throwing water over St. Magnus' steeple excited the wonder, as well as gratified the curiosity of the citizens, for fire engines had not then been invented. It was not until 1663 that the force pump was used in the construction of fire engines. Prior to this all the engineering skill of the Romans, as well as the contrivances heretofore adopted for supplying London with water, had evidently been formed upon the well-known principle that water will flow along any channel that has the slightest inclination downward, but the purpose of Morice's machinery was to impel the water in an ascending direction, and thus supply water in places higher than the source. The success of Morice's invention was so patent that the city authorities of London gave him an additional grant for two other arches under the London Bridge; this second grant was for 2000 years, and was finally secured by the New River Water Company.

In 1731, there appeared in the "Philosophical Transactions" a very minute account of the once greatly admired London Bridge Water-works by Mr. Brighton, an engineer, who carefully described them and accompanied his account with an engraving which had proper references for its elucidation; but whether at that time all the works were precisely the same in form and action as those first constructed, or if any improvement had been introduced, is not stated, and it may be right to premise that the water-wheels and machinery being fixed in strong frames of oak, they gradually rose and fell with

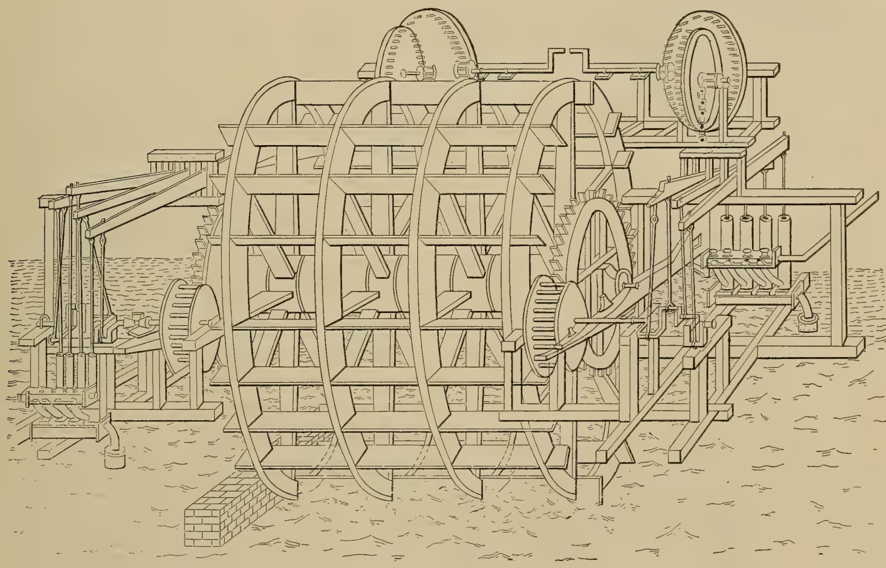


A VERTICAL WORTHINGTON ENGINE.

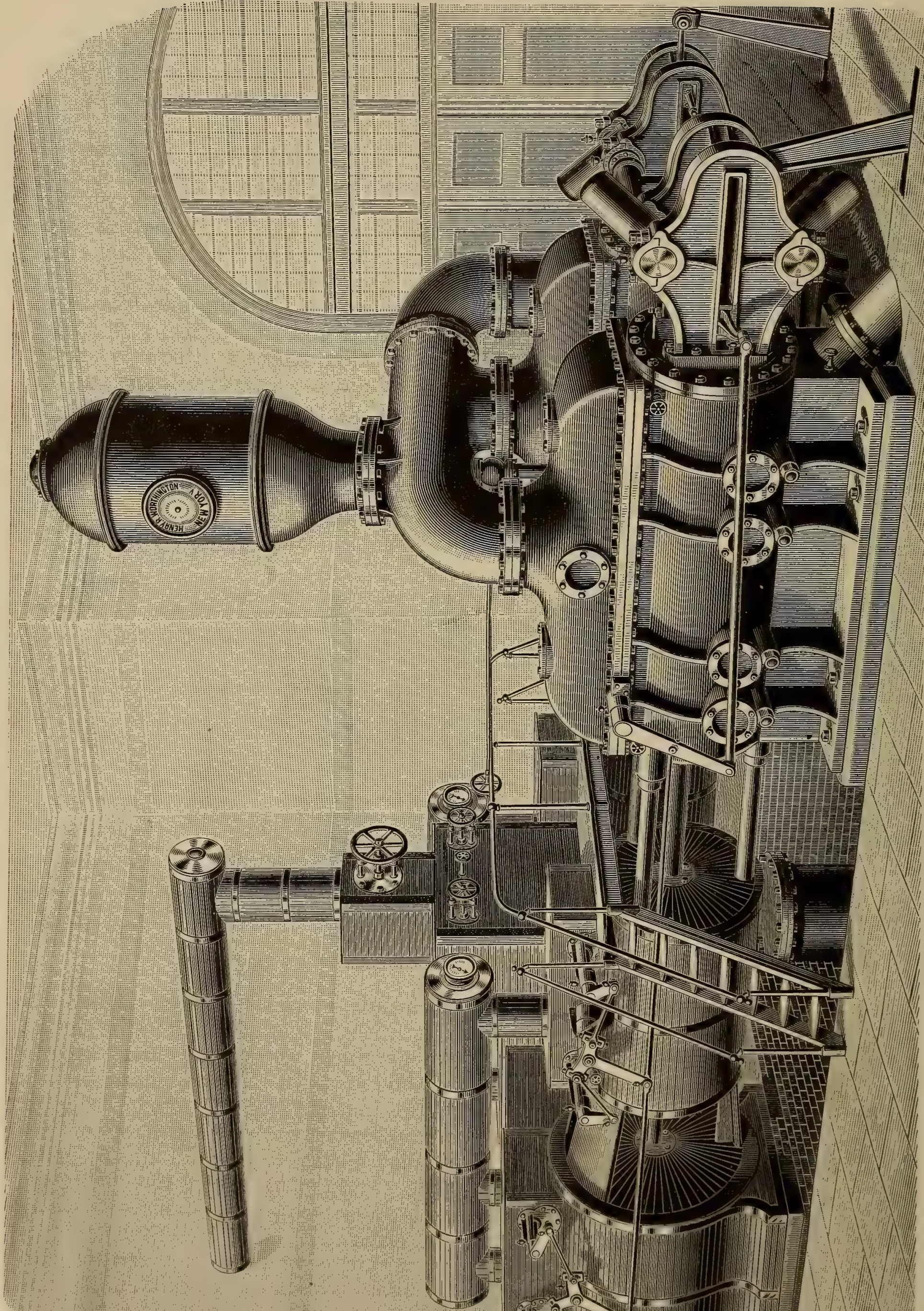
the tides. At that time there were three water-wheels of the respective diameters of nineteen and twenty feet. The pumps used had cylinders with a length of four feet nine inches, and an interior diameter of seven inches above, and nine inches below the valve. The cylinders of the pumps were fixed to the top of an enclosed, square, iron cistern, which had appropriate apertures, with valves just below the places where they were attached, these being worked by cranks which the revolving of the water-wheels kept in constant motion whenever the tides were flowing either up or down the river. One wheel communicated motion to sixteen pumps, and their cranks were arranged for four of them to work alternately, so that each set might draw its supply of water in succession.

One turn of the wheel occasioned the whole of the pumps to make 114 strokes, and when the tide flowed quickly it produced six revolutions per minute ; thus the number of strokes in that short time amounted to 684, which raised 1954 hogsheads of water in one hour. The accompanying sketch, taken from the engraving above alluded to, gives a good idea of the wheel and pumps of over three hundred years ago that revolutionized the method of supplying water to towns and cities to elevations higher than its source, and was the first application of piston pumps to direct pressure for the forcing of water.

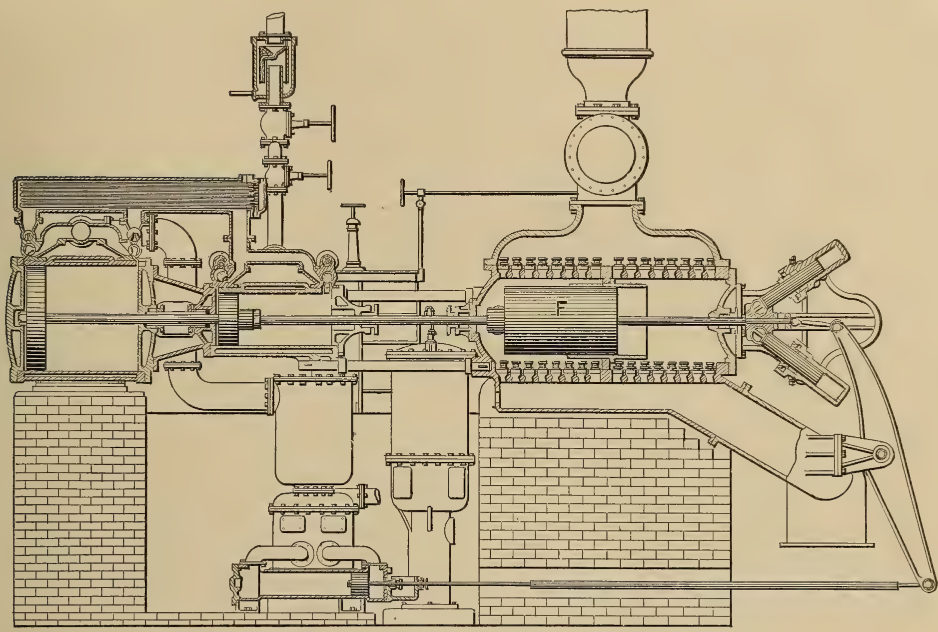
What a transformation, however, there has been since the establishment of the London Bridge pumping works of 300 years ago ! Ponderous machinery has grown out of the early feeble efforts, and a maze of cylinders, wheels, rods and levers, bewildering to the uneducated mind, has supplanted the erstwhile simple apparatus, making what to-day is generally known as the high-duty pumping engine. Undoubtedly a very great advance in the design of pumping machinery was accomplished by the introduction of the Worthington direct-acting duplex pump, consisting substantially of two similar pumps, placed side by side, with mechanism so arranged that the rod of one pump operates the valve of the other. By this beautiful arrangement one valve is opened and the corresponding piston begins its stroke just before its companion comes to rest, and the motion of the water column is thus made continuous. While this pump is about all that could be desired,



PUMPING MACHINERY FOR LONDON'S WATER SUPPLY 300 YEARS AGO.



HIGH-DUTY PUMPING ENGINE, BUILT BY HENRY R. WORTHINGTON, NEW YORK.



LONGITUDINAL SECTION OF A WORTHINGTON HIGH-DUTY PUMPING ENGINE.

so far as its operation is concerned, it is not possible to obtain a higher degree of steam expansion than that resulting from the use of ordinary compound steam cylinders, in which steam is followed practically full stroke in the high-pressure cylinders. A compound pumping engine of this type cannot be expected to show a duty much above seventy million foot-pounds.

At about the time that Mr. Henry R. Worthington had brought the low duty pumping engine to its highest possible state of development, his long and useful career came to an end. His son, Mr. C. C. Worthington, completed the labor of his honored father by adding the compensating device to the direct-acting engine, the office of which is the same as that of the fly-wheel in the crank and fly-wheel engine. Thus was produced the Worthington direct-acting, high-duty pumping engine, by means of which the highest pumping engine duties were obtained for the first time in an engine of the direct-acting type. The illustrations on this and preceding pages represent such an engine in general use for city waterworks and other places where large quantities of water are required to be pumped with an economical consumption of fuel. The simplicity of design renders it easy of maintenance, while the inexpensive foundations and small space occupied reduce the cost of installation to a minimum. It also possesses the advantages of great reliability and regularity of action and is automatically guarded against accident, which might result from a breakage in the force main.

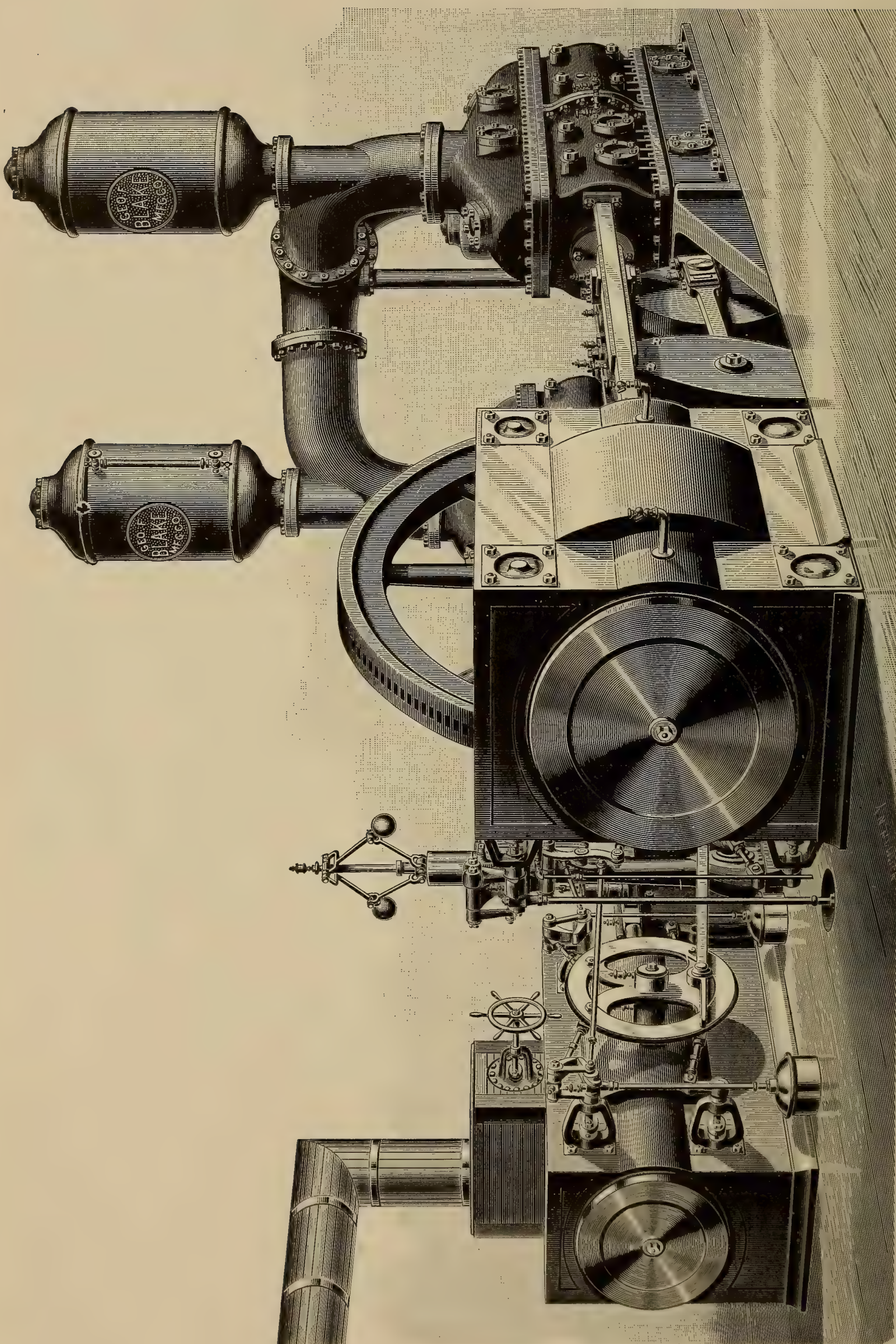
The pump end of this machine consists of two separate water cylinders placed side by side, securely bolted to the foundation. The suction chambers are below, cast on the main cylinders, and are connected by a cross suction pipe, leaving but a single opening for the suction main. The delivery chambers are bolted to the top of the water cylinders and are also connected by a cross pipe, with a single opening for the delivery main. The cross delivery pipe is surmounted by an air chamber, which is kept replenished by an independent air compressor of small size. The water cylinders are divided at their

middle section by diaphragms, cast in. To these diaphragms are bolted horizontal rings, lined with composition metal, through which the double-acting, cast-iron plungers work. When gritty water is to be pumped, the plungers work through stuffing boxes instead of solid rings. Above and below the plungers, and separating the suction and delivery chambers from the water cylinders, are the valve plates, which are also cast in place. The valve seats are of composition and are screwed into the valve plates. The valves themselves are rubber discs of small diameter, working on brass stems and are closed by helical springs. The backs of the valves are protected from the springs by metal plates and the area of opening and the lift are such as to give ample water way and ensure quiet seating.

The steam end consists of a high and a low-pressure cylinder, arranged tandem and in line with each water cylinder, to which they are bolted by cast-iron frames. The low-pressure cylinders rest upon expansion plates and are not bolted to the foundation, as the strains are all self-contained. The steam pistons are both connected directly with the plunger rod ; hence, all have the same length of stroke. The steam pistons are of box form, fitted with adjustable packing rings, scraped to fit and expanded by continuous steel springs. The steam valves are of the semi-rotative cylindrical pattern and are placed at either end of the steam cylinders, in such manner as to leave the smallest possible clearance space. They work in chests cast on to the steam cylinders and are worked by an arm from the piston rod of the opposite side of the engine, after the manner of the Worthington duplex motion, while the cut-off valves are operated by an arm attached to the piston rod of their own side of the engine. These valves are partially balanced to reduce sufficiently the power required to move them and the amount of oil necessary for lubrication. The valve motion links are adjustable.

Advantage is taken of every device to secure high economy in steam consumption. The steam is all passed through a separator, to trap off the entrained water, before entering the cylinders. Reheaters, through which steam at boiler pressure is circulated, are also provided for passing the steam from the high to the low-pressure cylinders. The steam cylinders themselves are jacketed, both on their sides and ends, and the condensed water from the jackets and reheaters, as well as that from the separator, drains into a closed tank, whence it is pumped back into the boiler by a small, automatically controlled steam pump, without loss of sensible heat. All heated parts of the engine are covered with a non-conducting material and enclosed in black walnut or other suitable lagging. The exhaust steam passes into a condenser, placed under the high-pressure cylinders and resting on the air pump valve chamber. The air pump barrels are lower than the valve chamber and are consequently always flooded The air pump pistons work horizontally and are driven by beams from the main crossheads. When the conditions render it more desirable, the air pumps and condenser may be placed above the main floor, on a level with the main engine, or a Worthington independent air pump and condenser may be used. The condenser may also be of the surface type, located either in the suction or in the delivery main and arranged to use the water pumped by the main engine for condensing the steam.

The high-duty attachment, allowing the steam to be cut off early in the stroke, thereby obtaining the economy due to its expansion and at the same time ensuring uniformity of stroke, consists of two compensating cylinders on each side of the engine, placed in juxtaposition to each other and supported by frames, in such manner as to oscillate freely back and forth with the motion of the engine. These cylinders contain water and a single pipe with branches communicates with each, through hollow trunnions. The plungers which work in these cylinders are fitted with tee-heads which press against a cross-



CROSS-COMPOUND PUMPING ENGINE, BUILT BY THE GEO. F. BLAKE MANUFACTURING COMPANY, NEW YORK.

head attached to the main piston rod, so as to retard the motion of the pistons during the first half of the stroke and assist it during the latter half. A glance at the diagram on this page will readily explain this action. The pressure in the compensating cylinders is derived from the force main and is subject to the same variations. In order to keep the compensating cylinders small in diameter, a differential accumulator is interposed between them and the air chamber, which serves merely to increase the pressure in the former a certain fold. In this attachment also lies the safety device. By a sudden breakage of the main the pressure would be relieved from the compensating cylinders at the same time that it left the air chamber, and the expanding steam not

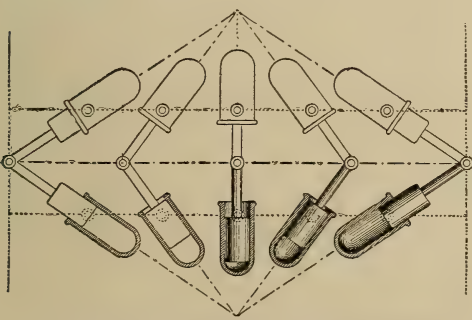


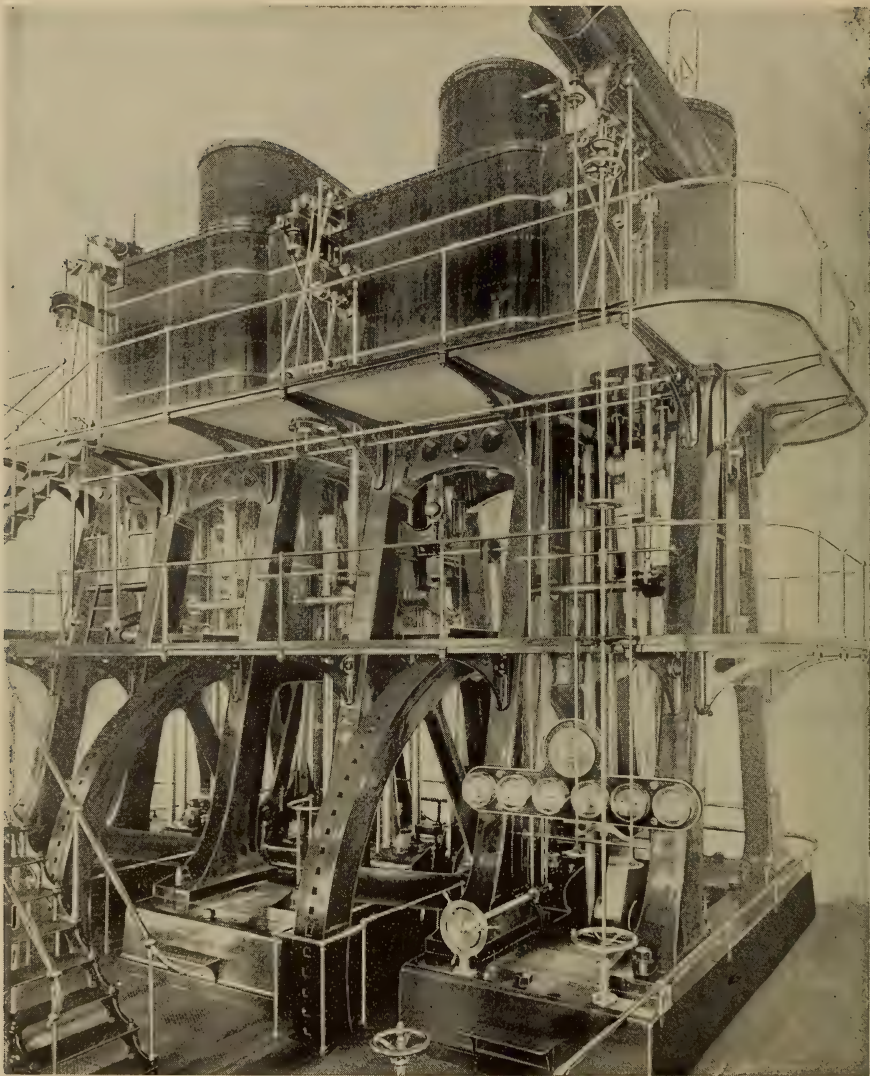
DIAGRAM ILLUSTRATING THE ACTION OF THE WORTHINGTON COMPENSATING CYLINDERS.

having sufficient power to drive the pistons to the end of the stroke without this assistance, the engine would quietly come to a stop. This has been frequently found to be the case when such an accident has occurred in practice.

The same amount of expansion can be obtained in the same engine whether running at a piston speed of ten feet per minute or at one hundred and fifty. This latter feature is one of great importance, affecting, as it does, so favorably, the economy of the engine when applied on any service where the demand is irregular or intermittent. The work of the compensating cylinders can, at the will of the attendant, be thrown on or off the engine instantaneously. Should they or the cut-off mechanism become in any way disarranged, or require overhauling or repairs, they can be quickly disconnected from the engine, which can then be run as economically and satisfactorily as though originally constructed without them. The compensating cylinders can be placed between the steam and water cylinders or carried by frames attached to the outside ends of the water cylinders.

Of the large line of pumping engines built by the Geo. F. Blake Manufacturing Company, the one shown on page 42 represents one of their latest and best examples. While already referred to in one of the earlier numbers of this magazine, it is here reproduced as of renewed interest for the purpose of comparison. The engine is of the direct-acting, fly-wheel, cross-compound type, having one high-pressure and one low-pressure steam cylinder with two double-acting inside plunger pumps. Both high and low-pressure cylinders are provided with valve gears of the Corliss type. The valves are closed by vacuum dash-pots with internal communications between the vacuum and cushion pressure, and the action of the gear is smooth and noiseless without clicking or hissing. The steam cylinders are jacketed on the barrels and on the heads, the jackets being cast with the cylinders. The steam for supplying both the cylinders and the high-pressure jacket is brought to the steam chest on top of the high-pressure cylinder; the jacket on that cylinder is in free communication with the steam chest, and the condensation in it is drained away from the bottom of the jacket through a trap.

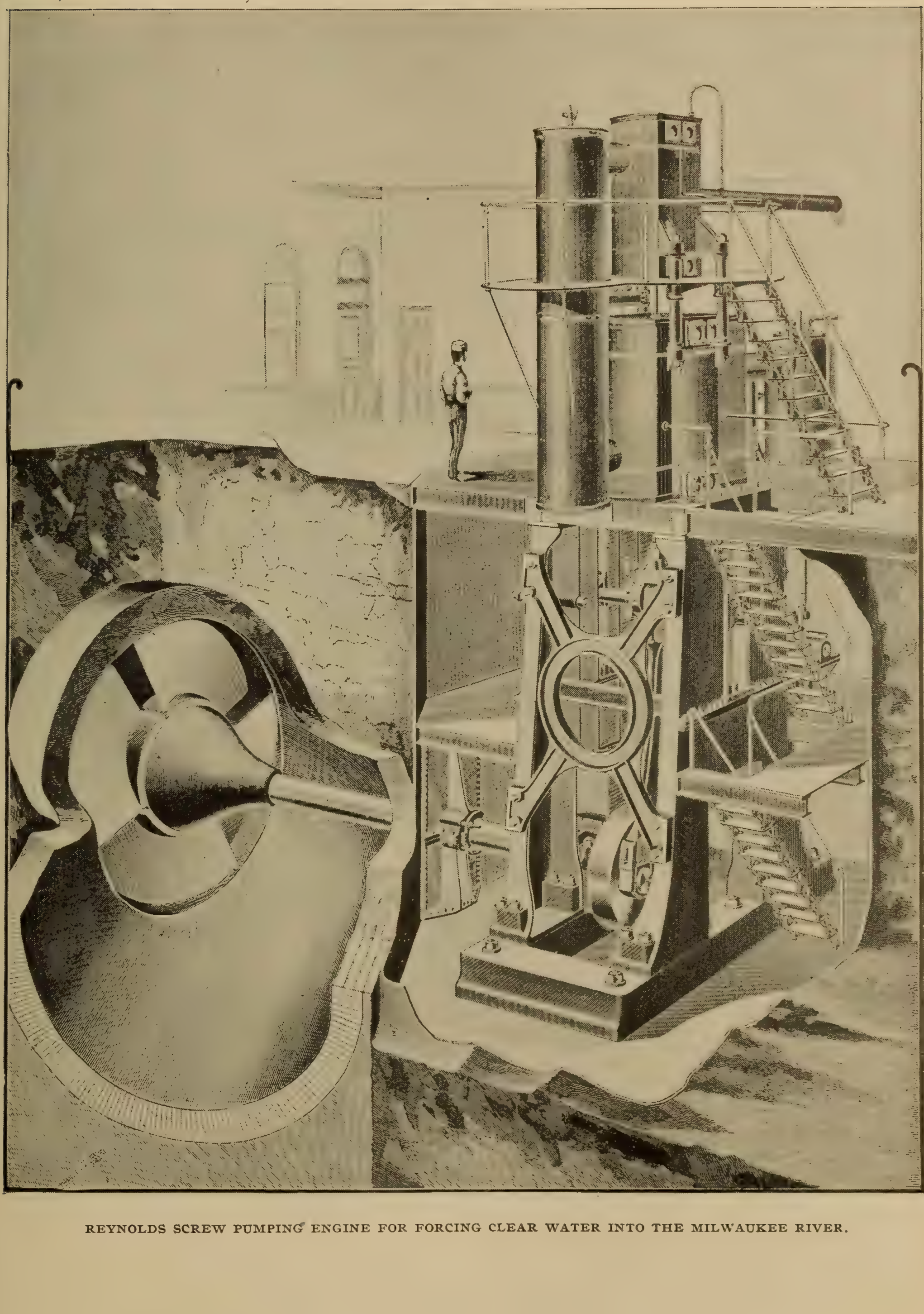
The steam from the high-pressure cylinder exhaust space passes down into an intermediate receiver, which contains a tubular reheater, thence up through the low-pressure cylinder jacket and into the low-pressure steam chest. The reheater is supplied with steam under full boiler pressure, and the condensation is returned, under normal conditions, directly to the boiler by a special feed pump driven by the main engine.



TRIPLE EXPANSION PUMPING ENGINE, BUILT BY THE E. P. ALLIS COMPANY, MILWAUKEE, WIS.

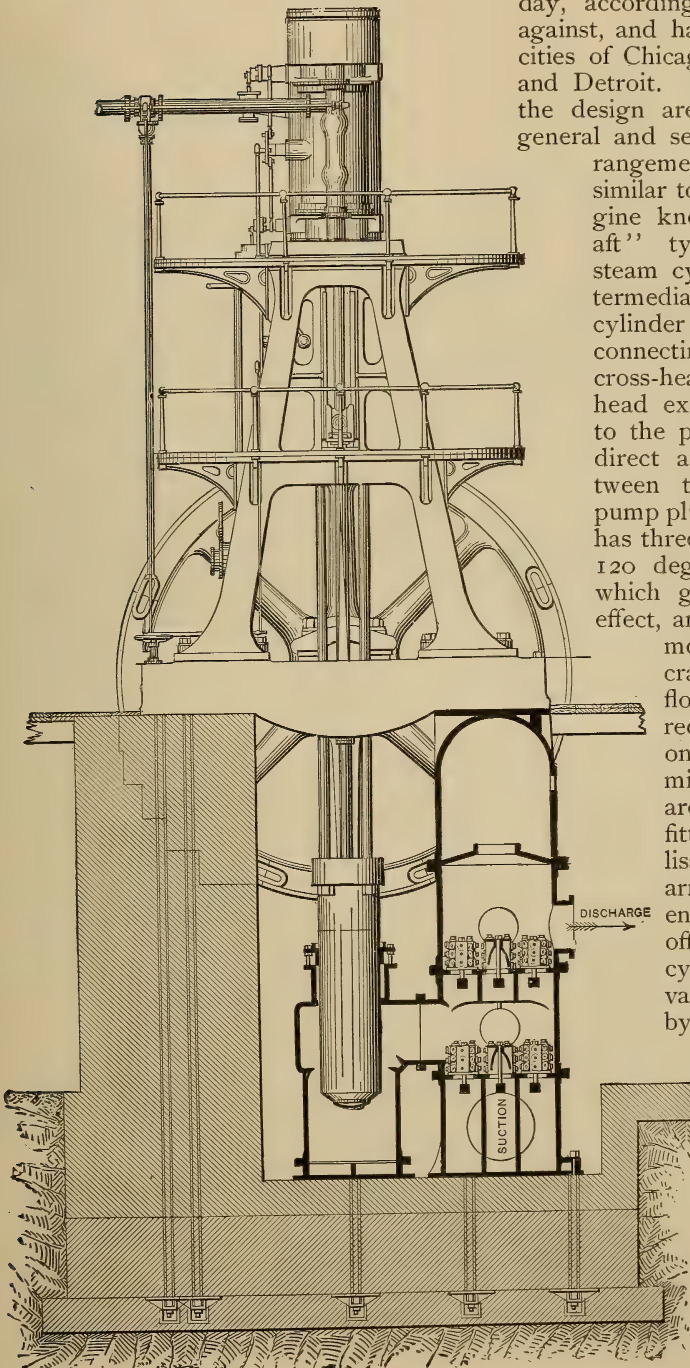
To Mr. Edwin Reynolds, of the E. P. Allis Company, of Milwaukee, Wis., belongs the credit of bringing out the first triple-expansion engine ever constructed for water-works purposes. The one of which an illustration accompanies this article belongs to that type and has shown the highest duties ever reached by any pumping engine, tests made at the Milwaukee Water-works having demonstrated the attainment of the following performances: 152,448,000 foot-pounds for each 1000 pounds of steam used; 143,306,470 foot-pounds for each 100 pounds of coal burned; and 137,656,000 foot-pounds for every 1,000,000 British thermal units. The steam consumption was 11.68 pounds per indicated horse-power per hour, being the lowest ever recorded. Tests of five similar engines in the Chicago Water-works gave results of from 142,000,000 to 149,000,000 foot-pounds duty for each 1000 pounds of steam used.

The design is suited for capacities of



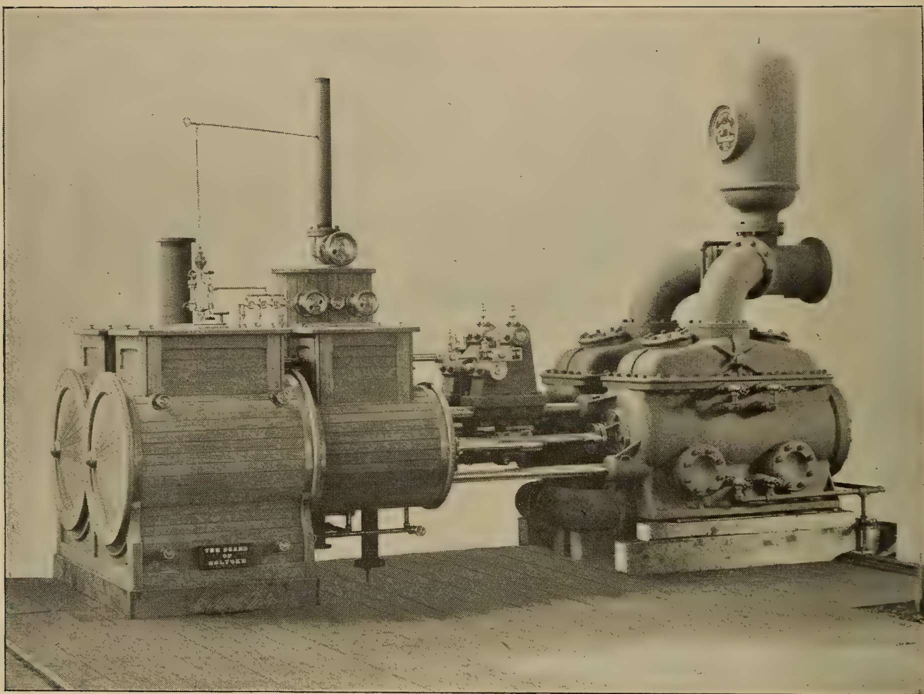
REYNOLDS SCREW PUMPING ENGINE FOR FORCING CLEAR WATER INTO THE MILWAUKEE RIVER.

from ten to thirty million gallons per day, according to the head pumped against, and has been adopted by the cities of Chicago, Omaha, Milwaukee, and Detroit. The general features of the design are clearly shown in the general and sectional views. The arrangement above the floor-line is similar to that of the marine engine known as the "fore-and-aft" type. There are three steam cylinders, "high," "intermediate," and "low," each cylinder having two piston rods connecting to a forged steel cross-head, and from this cross-head extend four steel tie-rods to the plungers, thus forming a direct and rigid connection between the steam pistons and pump plungers. The main shaft has three cranks, set at angles of 120 degrees from each other, which gives a steady turning effect, and as the pump plungers move in unison with the cranks, a perfectly uniform flow of water is obtained, reducing the shock and jar on pumps and pipes to a minimum. The cylinders are steam jacketed and fitted with Reynolds–Corliss valve gear, specially arranged for this type of engine, adjustable trip cut-offs being provided for each cylinder, the high-pressure valves being also controlled by a speed governor. The throttle valve, injection valve for condenser, cut-off levers, etc., are all placed conveniently, so that the engine can be stopped, started and controlled from one position on the engine room floor.



SECTION OF PUMPS OF THE ALLIS ENGINE.

The pumps, which are located below the engine bed-plates, are of the single acting, outside packed,

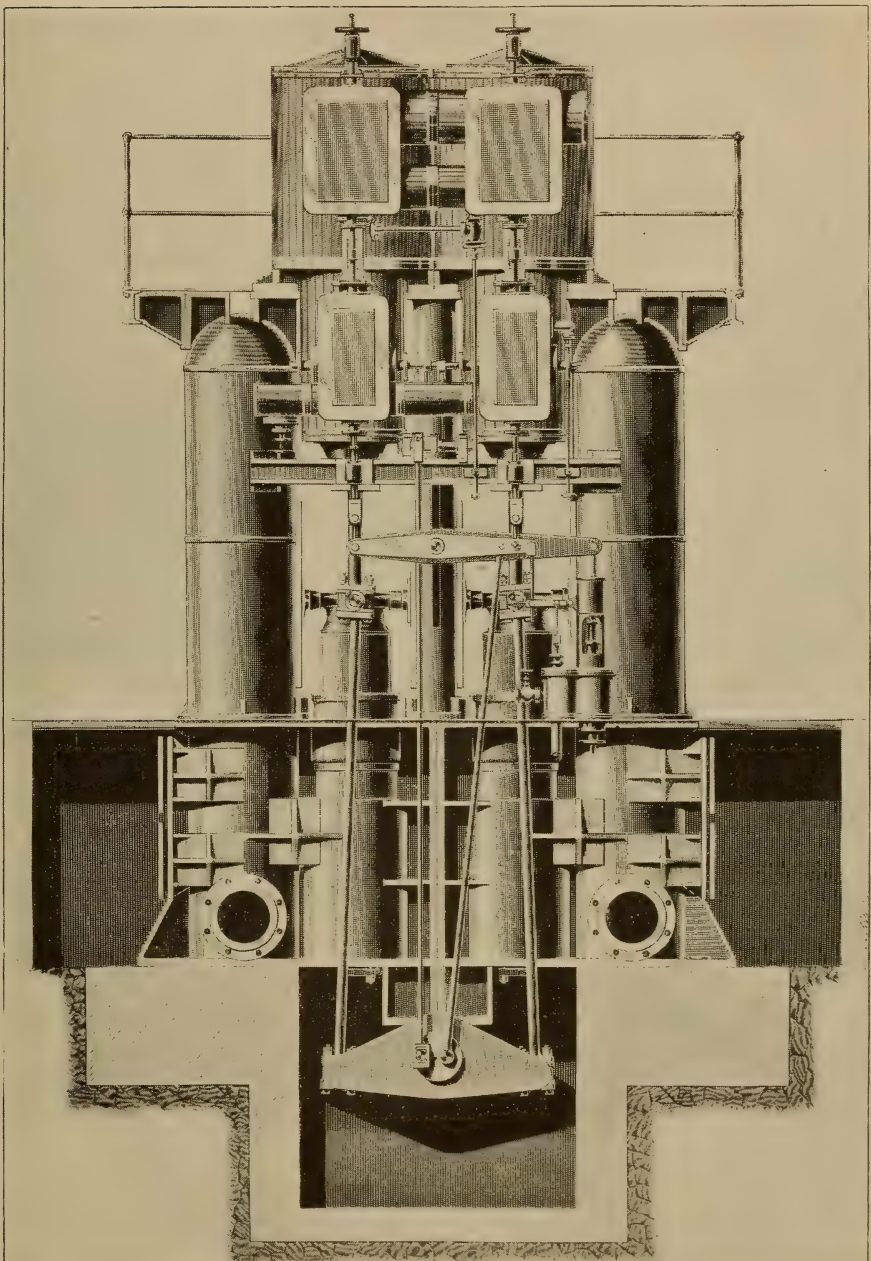


COMPOUND DUPLEX PUMPING ENGINE, BUILT BY THE DEANE STEAM PUMP COMPANY, HOLYOKE, MASS.

plunger type, and are provided with large valve area, insuring quiet working at high piston speeds. The pump valves are of medium hard rubber, and are arranged in groups mounted on cages, which are easily removable, manholes being provided, to give easy access to the interior of the pumps. The pumps can be placed any required distance below the engine room floor by simply extending the plunger connections. The air and feed pumps are driven direct from the main engine, and the condenser may be either of the surface or jet type, as local conditions require.

It is not uninteresting in this article to once more bring to notice also a rather novel pumping engine designed by Mr. Reynolds and built by the Allis Company several years ago for the city of Milwaukee, for flushing the Milwaukee river during the summer months with clear water taken from Lake Michigan. The engine has a rated capacity of 32,000 cubic feet per minute, or about 345 million gallons in twenty-four hours, raised 4½ feet high, but in actual operation the amount pumped varies between 400 and 500 million gallons in twenty-four hours. The pump is of the propeller type, the diameter of the propeller being 14 feet and the pitch 8 feet. The wheel is located in the mouth of a 12-foot tunnel. The pump is driven by a vertical steeple compound engine. The duty guaranteed for this machine was 70 million foot-pounds for each 100 pounds of coal burned, and the duty obtained at the official trial was 76 million foot-pounds.

The latest form of construction of the Deane Steam Pump Company, of Holyoke, Mass., is that shown on this page, the particular engine represented having a capacity of 2,000,000 gallons per twenty-four hours. The general design is that well known as the compound condensing duplex, and for small and medium sized water-works duty it has probably never been ex-



TRIPLE EXPANSION PUMPING ENGINE, BUILT BY MESSRS. HATHORN, DAVEY & CO., LEEDS, ENGLAND.

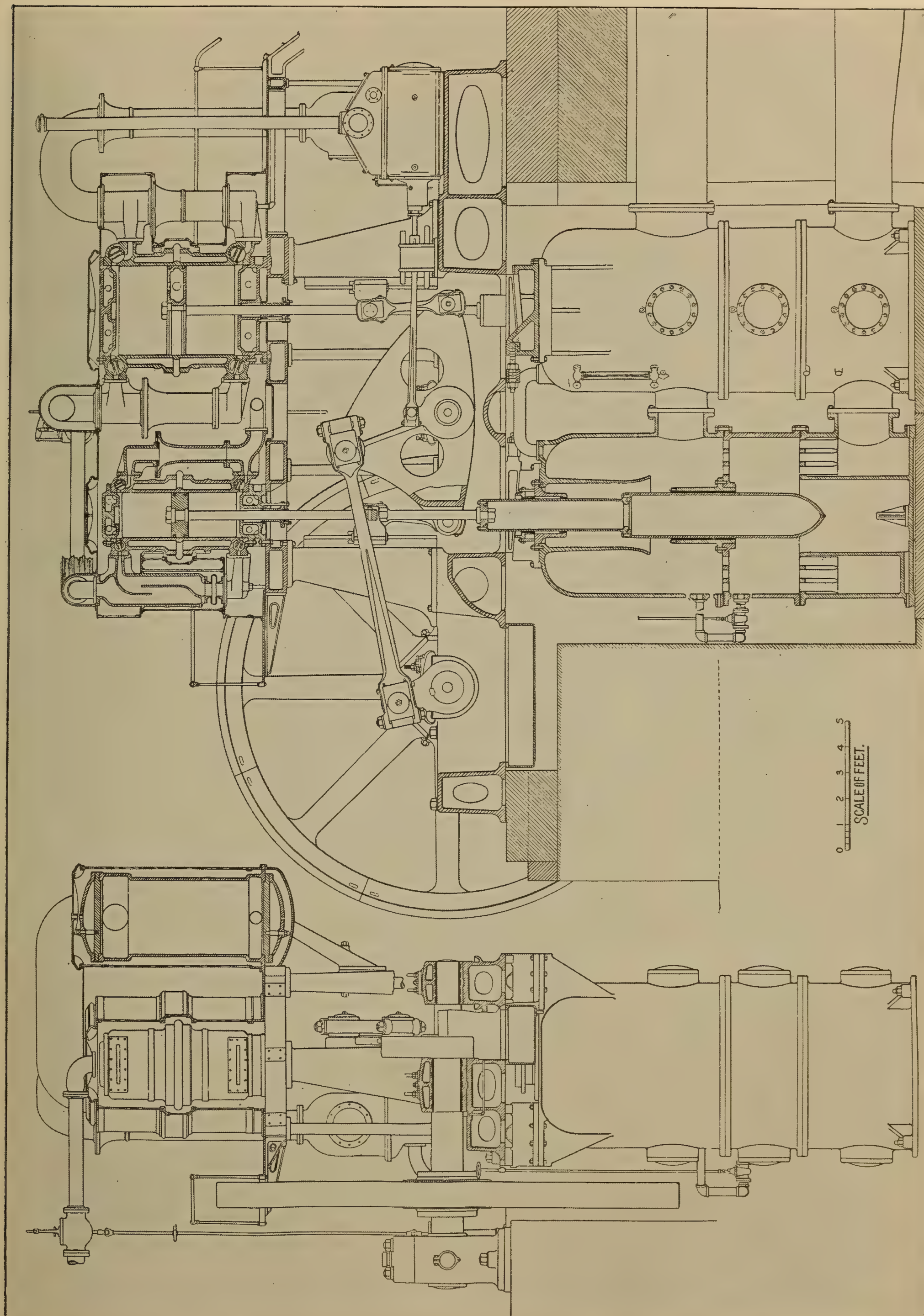
celled. The excellence of the machine consists in the care with which the details have been worked out. Each steam cylinder is in one piece with its jacket. The cylinders are cast with one head in and the connecting rods between the steam and water ends are attached to the cylinder casting,—not to the heads. These two features obviate all danger of having to remove the heavier castings to repair leaky joints. The three throttle valves,—one for each side and one in common,—with a separate oil feed to each of the four cylinders are together, accessible and outside the lagging. The boxes for the rock shafts have removable caps so that the levers and cranks can be shrunk onto the shafts. The lagging consists of cast-iron frames held together with removable pins, the strength of the structure not depending at all on the cabinet work, which is simply fastened to the frame. The water cylinders have large valve areas and are provided with ample and convenient hand holes. The specials connecting them are built with ample radii and the two suctions are connected by a "run-around" of large size. Each separate chamber is provided with proper valves and pipe so that it can be filled or drained. In the whole machine the material is so disposed as to give the maximum strength without clumsy and useless members.

A later design of engine, built by the Blake Company for the Boston Waterworks, and known as Mystic Pumping Engine No. 4, is shown on the opposite page. It was designed by Dr. E. D. Leavitt and is of the familiar beam and fly-wheel type with differential plungers. The engine is intended to deliver 10,570,000 gallons in twenty-four hours when running at 51 revolutions per minute, equivalent to a piston and plunger speed of a little over 400 feet per minute. It is this speed which is one of the noteworthy features of the engine.

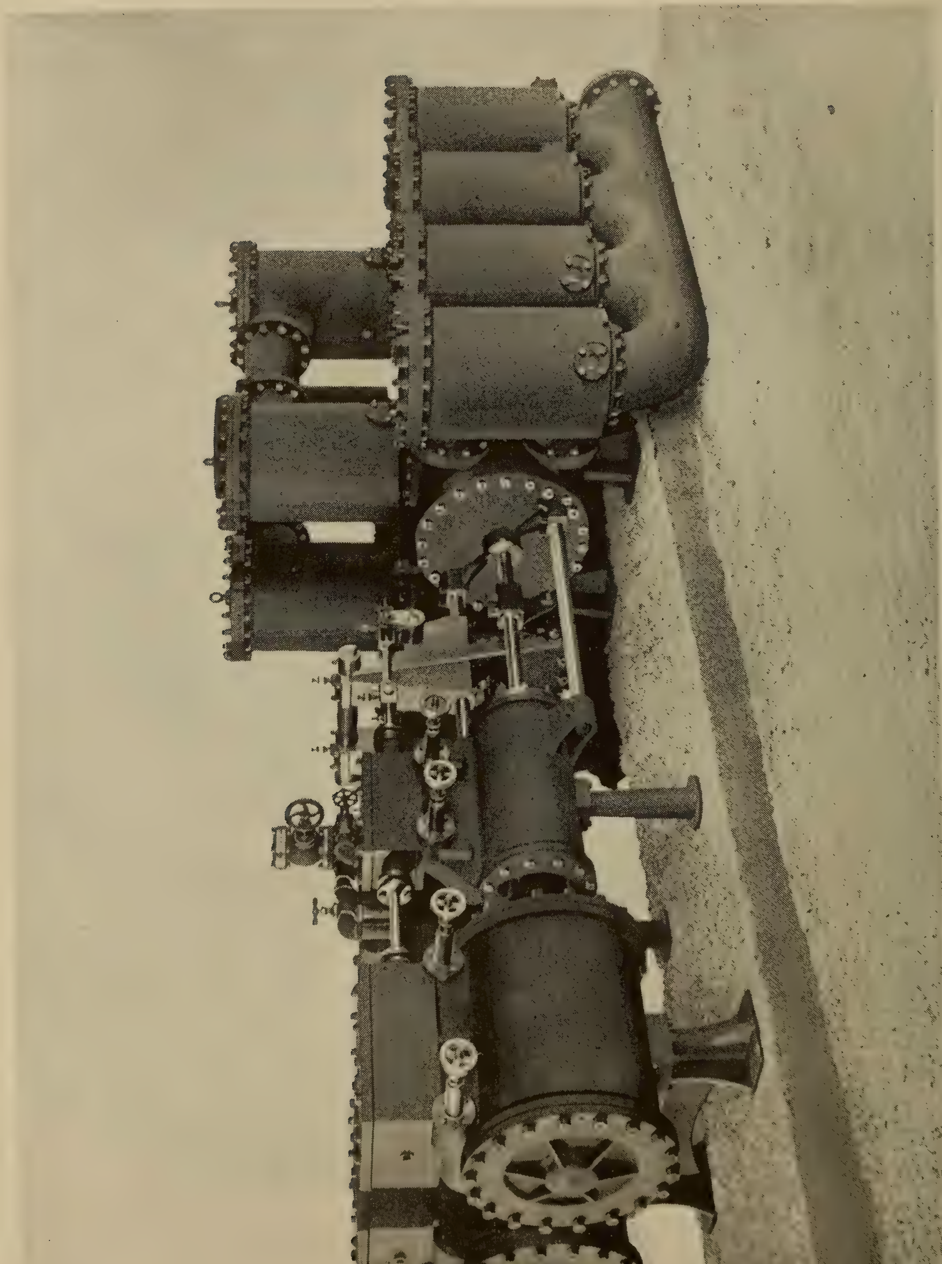
The high-pressure cylinder is 21 inches in diameter and counterbored 21¼ inches at each end, the length between counterbores being 4 feet 5½ inches. The steam jacket is cast with the cylinder, as are all the valve chests, this being done with the low-pressure cylinder as well. The low-pressure cylinder is 42 inches in diameter inside, counterbored a quarter of an inch more at each end, its length between counterbores being 4 feet 6½ inches. The jackets of both cylinders are cut at their middle portion and the openings made in this way are covered with a copper expansion ring. The jackets on both cylinders and cylinder heads are supplied with steam taken from a 1½-inch pipe connected with the main steam pipe on the boiler side of the throttle. The form of the cast-iron beam is plainly indicated on the side elevation; the journal about which it rocks is 10 inches in diameter. The crank-shaft of the fly-wheel is 12½ inches in diameter and carries a crank of 2-foot throw. The fly-wheel is 18 feet in diameter and weighs about 17 tons.

The water ends are made in three sections. The discharge from the pump worked by the high-pressure piston will be into the delivery chamber of the pump worked by the low-pressure piston, and similarly the suction main will connect with the low-pressure pump inlet chamber, with which the inlet chamber of the high-pressure pump will be connected.

A compound duplex engine, particularly designed for pumping sewage, and built by the Laidlaw–Dunn–Gordon Company, of Hamilton, Ohio, the successors to the Gordon Steam Pump Company, is also shown here. The pump end is of special construction and will handle common sewage with certainty and regularity. It is adapted for cities and towns where the location renders it necessary to deposit the sewage at some distant point. The pump valves, of special design, are of flexible rubber, fitted over oval brass hinge castings. When the valves are wide open they have a clear passage equal to 10 inches in diameter, and will pass all substances which are liable to be in the sewage. The pump shown has a capacity of 4,000,000 gallons in twenty-four hours. It is one of the three fur-



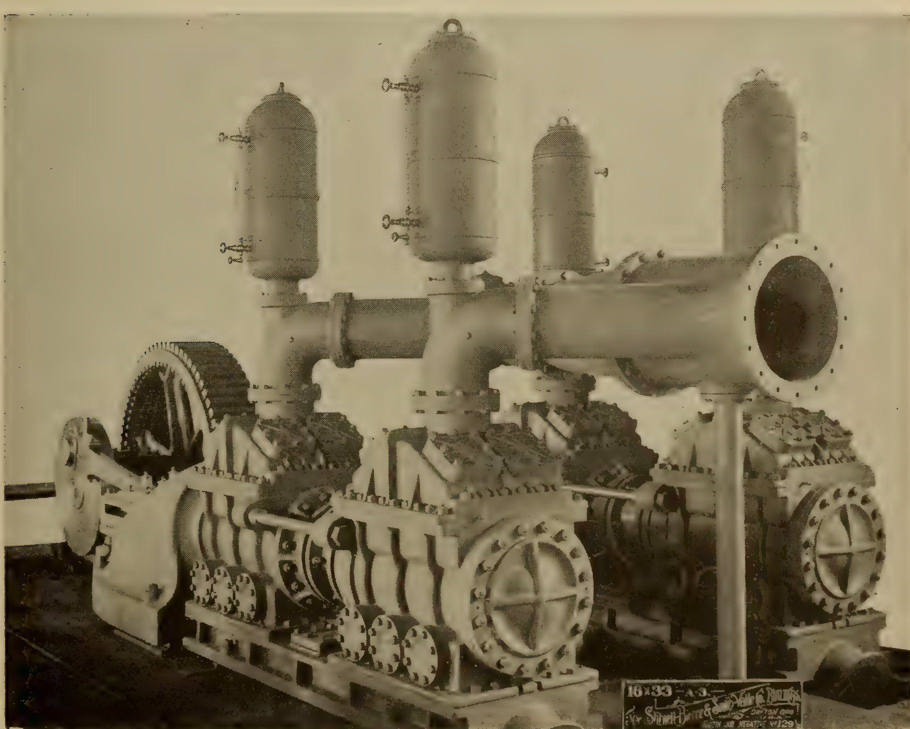
THE MYSTIC PUMPING ENGINE, BUILT BY THE GEO F. BLAKE MFG. CO NEW YORK.



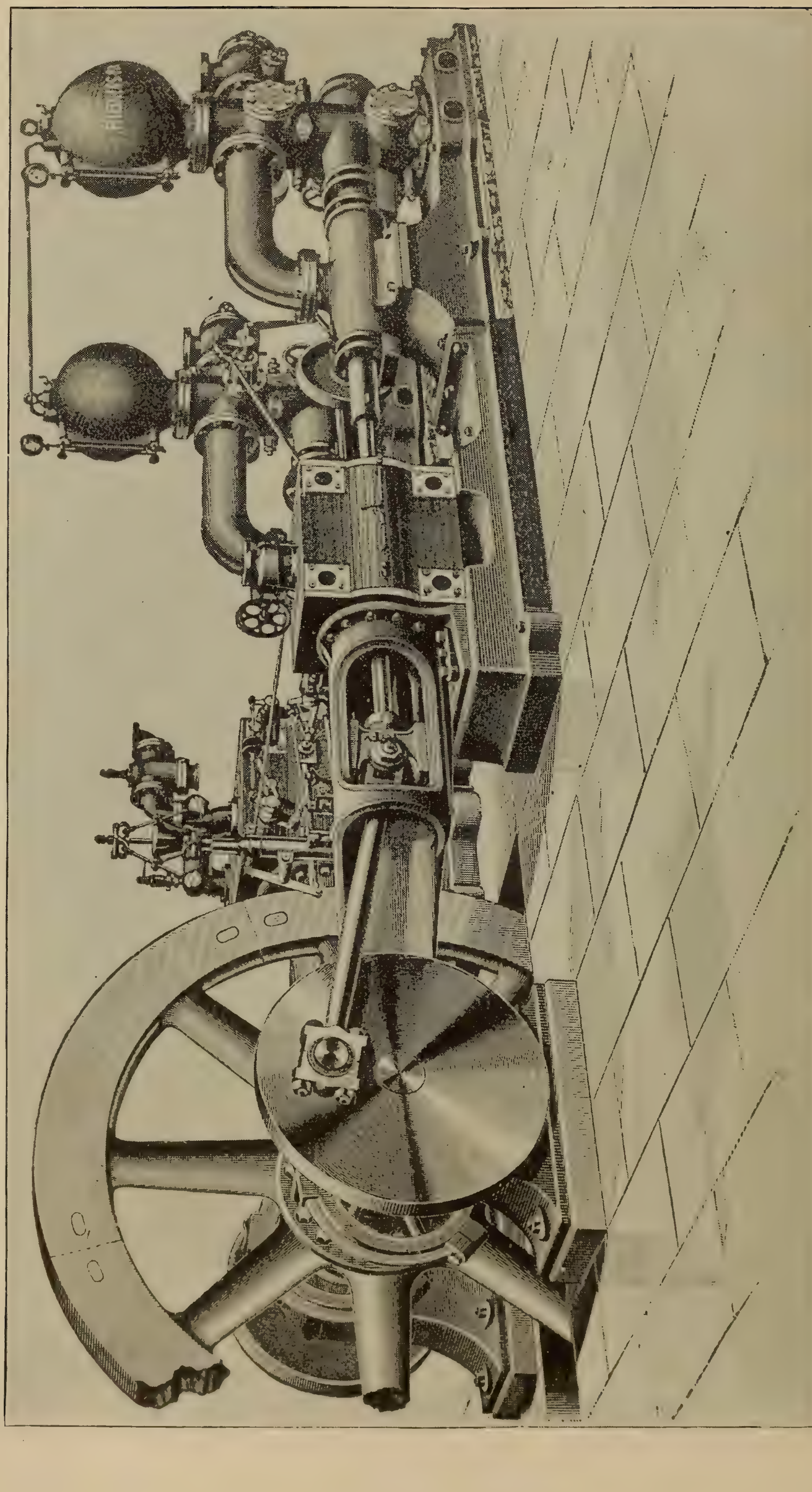
COMPOUND SEWAGE PUMPING ENGINE, BUILT BY THE LAIDLAW-DUNN-GORDON COMPANY, HAMILTON, O.

nished by the above-named company to the city of Chicago for the Woodlawn Park drainage system. It has high-pressure steam cylinders 14 inches in diameter, low-pressure cylinders 24 inches in diameter, and pump cylinders 20 inches in diameter, all having a stroke of 24 inches. The pump has four discharge valves, and eight suction valves all arranged in separate circular valve chambers, one valve to each chamber, which makes them easy of access. These pumps can be built either horizontal or vertical, in a capacity ranging from 500,000 to 10,000,000 gallons per twenty-four hours.

Still another design of pumping engine, recently furnished to the city of Austin, Tex., is here shown, being made up of two duplex, double plunger power pumps, each having a capacity of 4,000,000 gallons per 24 hours, delivered into the reservoir under a dynamic head of 165 pounds. The diameter of the water cylinders is 16¼ inches and the length of stroke, 33 inches. The valve area of both the suction and discharge valve decks is 55 per cent. of the area of the plungers. The engine beds are of the Tangye type, very heavy, with cast steel crossheads, adjustable slides, and very substantial connecting rods and stub ends. The shafts are of hammered steel, 11½ inches in diameter. The pumps are driven through mortise spur gears with 18-inch face by Victor turbine wheels. The weight of each pumping engine is upward of sixty tons. Each water cylinder takes its supply through a 16-inch suction pipe from the forebay, having a head of about ten feet of water on the suction valve, and discharges through two 18-inch discharge pipes into one 24-inch main, which leads to the reservoir. Each discharge box is provided with a large air chamber. The engines, as well as the turbines, were built by the Stilwell-Bierce & Smith-Vaile Company, of Dayton, O.



4,000,000 GALLON PUMPING ENGINE AT AUSTIN, TEX., BUILT BY THE STILWELL-BIERCE & SMITH-VAILE COMPANY, DAYTON, O.



THE RIEDLER PUMPING ENGINE, BUILT BY MESSRS. FRASER & CHALMERS, CHICAGO, ILL.

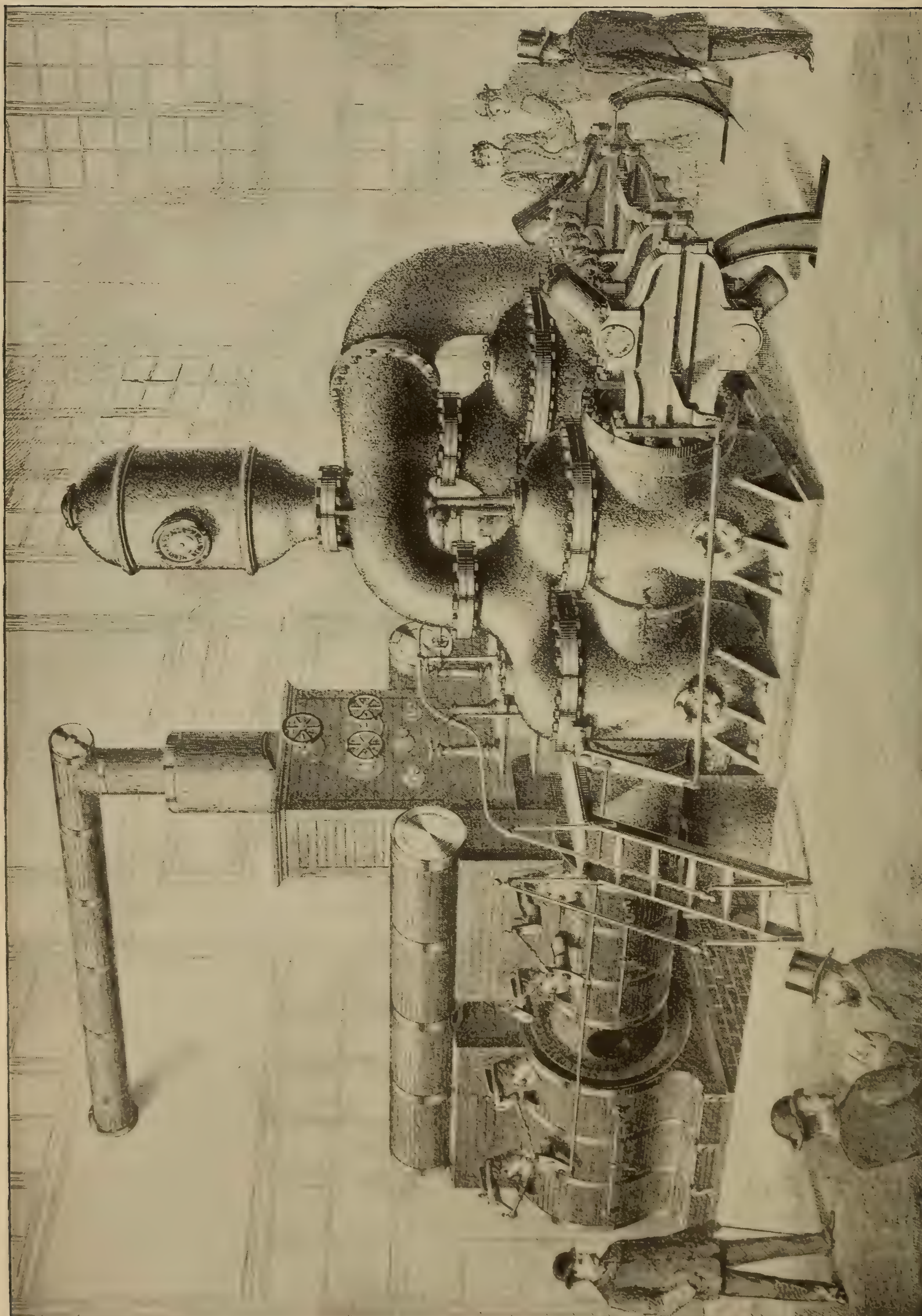
Not the least interesting of the several pumping engines now on the market is the Riedler mine engine, a German design, which is being introduced into this country by Messrs. Fraser & Chalmers, of Chicago. Abroad this engine has been remarkably successful and is rapidly coming into extensive use. The first experiment was made with the Riedler system as far back as 1884, when several engines for deep mines were built. They met at once with great favor. In one coal mine in Bohemia eight underground mining pumps of the Riedler system have been built in the course of four years, and since 1888 a large number of such pumping engines have been built in Austria, Germany, Belgium, France, Spain, Italy, and England. Their introduction in a great number of deep mines in Bohemia, Silesia, Westphalia, and Belgium has been specially notable.

The peculiarity of the Riedler pump lies in the valves. Ordinary pump valves are left to operate by themselves, and are liable to irregularity, and to cause danger; and such valves permit only a very small lift, thus throttling the water passage and requiring very large circumferential passages. Riedler valves operate with a liberal lift, avoiding any throttling, and are not left to operate by themselves, but are worked by a positive valve gear similar to that of an engine. This mechanism is exceedingly simple. Each valve is closed at the moment the stroke of the piston changes, and this closing is done by means of a spindle projecting into the valve chamber. Near the end of the stroke a very small free lift is allowed to the valve, which can be regulated at will, thus enabling the valves to accommodate themselves to variable pressure, or variable conditions of working under high speed. In high speed pumps, and also in pumps used for gritty water, springs are inserted either between the valve and its gear, or in the rods of the gear, thus allowing a compression of the spring without injuring the valves or their seats, or the gear, in case any hard material gets between the valve and its seat, or relief is required for water remaining in the pump. This spring serves to accommodate the action of the valve to any variable pressure or speed. The springs are so arranged that the ordinary resistance of the valves will not compress them.

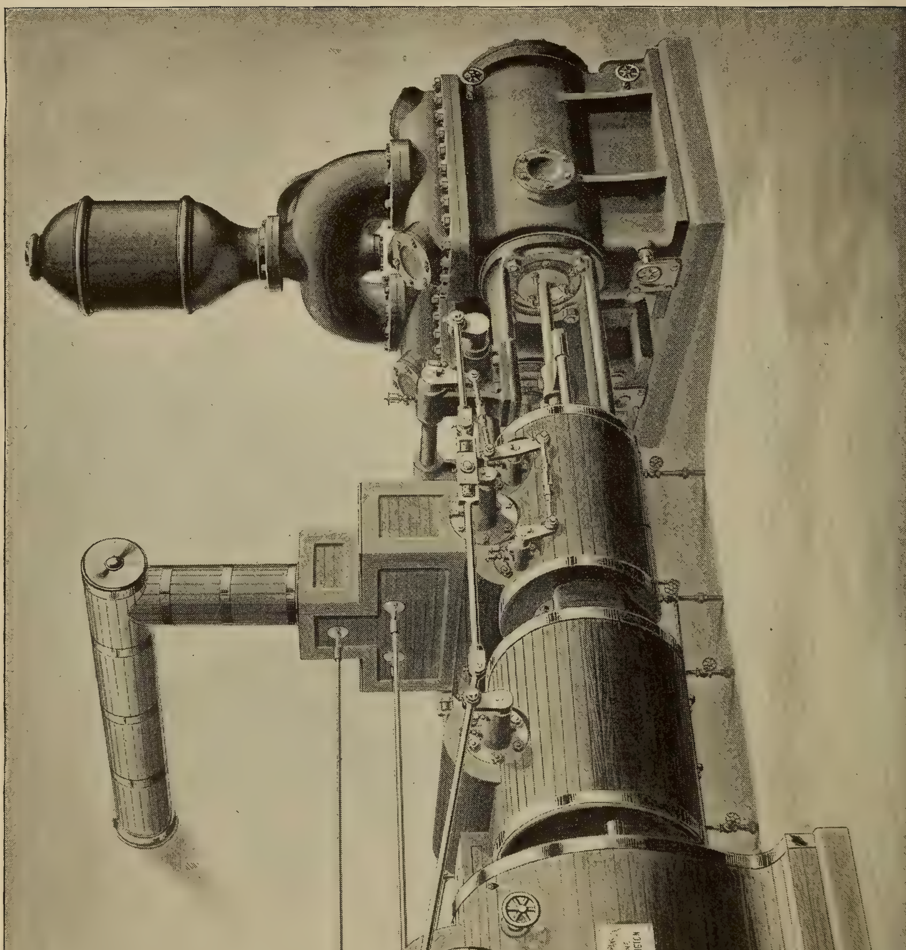
It might seem that the introduction of gear for operating the pump valves would lead to some complication, but instead of that, it actually simplifies the action compared with a pump of the ordinary type. On account of the very limited lift, it is usual to have all the way from 12 to 100 or more valves for suction, and as many for discharge. These valves require constant attention and renewals, involving unavoidable stoppages of the whole pumping machinery. But in the Riedler pumps the lift of the valves is not limited; consequently their diameter is made small, and as to number, only one suction and one discharge valve are required for each plunger, which enormously simplifies the inside arrangement, and the essential working parts of the pumps. What little valve motion there is, is on the outside where it is readily accessible for attention and adjustment. The valve motion can be driven through the same eccentric that operates the steam valves, and consists simply of small rods connected with the valves. The whole is simple in construction and easy to understand and adjust.

The first Riedler pump used in the United States was built by Fraser & Chalmers for the Boston & Montana Company, of Butte, Mont., with 5⅝ in. and 8 in. plungers, and 16 in. and 25 in steam pistons, all 24 in. stroke. Its duty is 900 gallons per minute lifted 600 feet in height. An illustration of this pump appears on another page. The engine proper is of the Corliss twin-compound, condensing type with a 16-inch high-pressure and a 25-inch low-pressure cylinder, the length of stroke being 24 inches.

A good example of English pumping engine practice is shown on page 49, representing a triple expansion engine, built by Messrs. Hathorn, Davey &



THE WORTHINGTON WORLD'S FAIR HIGH-DUTY ENGINE.



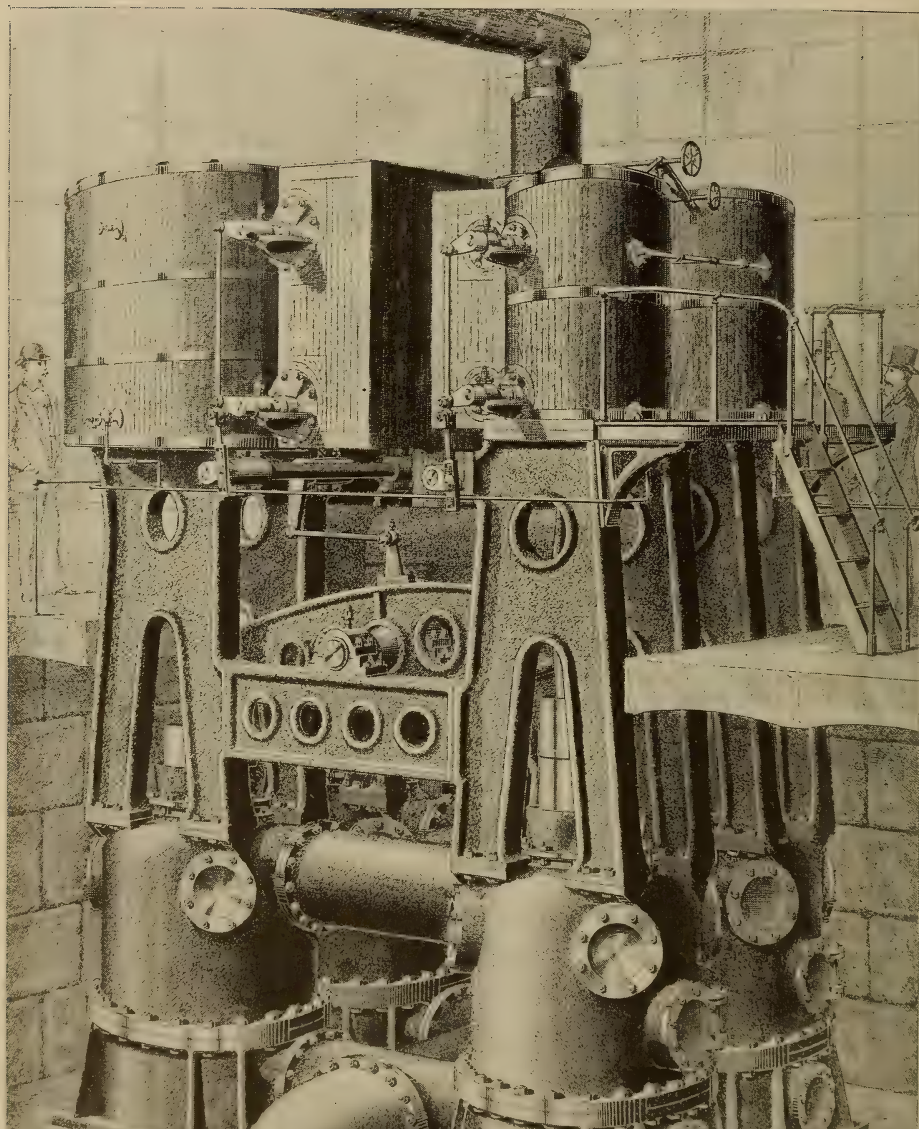
SIX-CYLINDER TRIPLE EXPANSION WORTHINGTON PUMPING ENGINE.

Co., of Leeds. It is equipped with Mr. Henry Davey's compensating device by means of which a high degree of expansion is secured without any rotative motion. There are two high and two low-pressure pistons connected by trunks and there are two pump plungers directly connected to the piston rods, one making an up-stroke while the other makes a down-stroke. The two plungers are connected by connecting rods taking hold of pins in a rocking-frame under the pumps, this frame constituting the compensating device. It is a simple contrivance consisting of a bent lever for causing the pump resistance to decrease from the beginning to the end of the stroke. The valve gear consists of main slide valves moved by a subsidiary cylinder, controlled by a cataract. On the backs of the main valves are expansion valves connected to the engine by levers so as to receive the motion of the main piston on a reduced scale. In operation, the steam is first admitted to the small high-pressure cylinders ; it is next expanded into the annular spaces around the trunks ; and from there it is finally expanded on the top of the large pistons, subsequently escaping to the condenser.

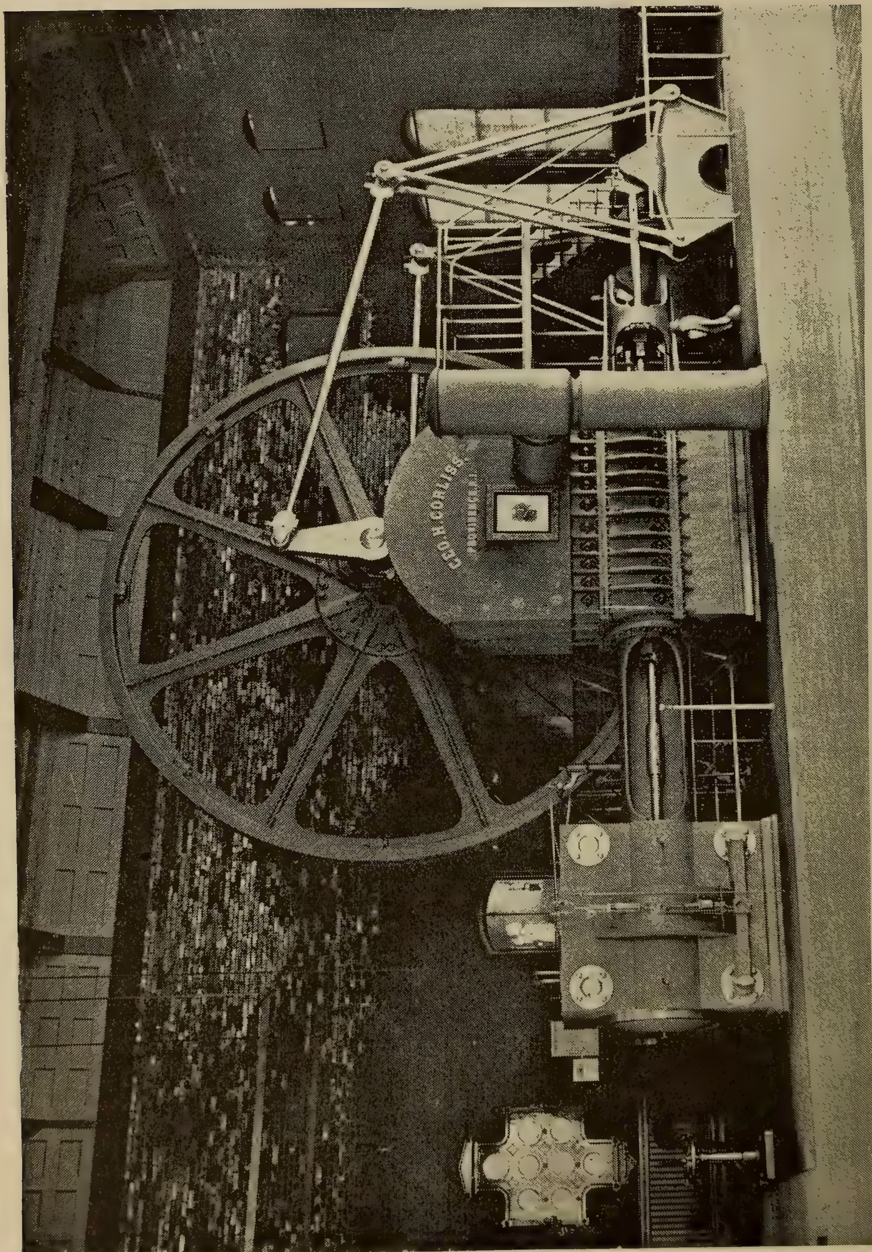
Another form of engine of Worthington design especially suitable for use in places where the available floor space is limited is shown on page 35. It is also in extensive use for waterworks of cities situated on Western rivers, where the rise and fall at diferent seasons of the year is so great as to require the pumps to be placed at the bottom of deep wells. The distance between the pumps proper and the steam end of the machine can be varied to suit any conditions of depth of the pump well. The steam cylinders and valve motion can be placed at a point high enough to prevent their being flooded by a rise of water, while, at the same time, the pumps may be kept so low as to be within easy suction lift, when the source of supply has fallen to its lowest stage. The foundations are of the simplest form and need not extend above the floor of the well. The main features of this engine are similar to those of the Worthington horizontal engine and exactly the same form of water valve, working on a vertical stem, is used. The plungers are double acting and are worked vertically, by means of rods extending out through the upper water cylinders, coupled directly to the steam piston rods. The low-pressure cylinders are supported by cast-iron frames, and the high-pressure steam cylinders are placed above and in line with the low-pressure. An important feature of this type of engine is the simple method of balancing the weight of the moving parts. This is accomplished by means of single acting plungers attached to the main piston rods and working in cylinders containing water, which are connected by pipes of ample size to a large air tank. The pressure in this tank can be accurately adjusted, so that the effort of the steam will be the same, whether the engine is moving upward or downward.

These engines may be fitted with plungers and rings or with packed plungers and with either surface or jet condensers. The air pumps may be attached to the main engine or be entirely independent. The steam end is readily built triple expansion, in which case the intermediate cylinders are placed between the low and the high-pressure cylinders. In some cases a patented four-cylinder triple arrangement is used, one high and one intermediate cylinder being on one side ot the engine, and one high and the low on the opposite side. Receivers with reheating tubes are then placed between the high and the intermediate and the intermediate and the low-pressure cylinders.

The latest form of Worthington engine is of the six-cylinder, triple-expansion type, shown on the opposite page. The engine, of the horizontal form, in its general construction follows that of the duplex-compound type originated by the builders of this engine, and although, broadly speaking, it is the compound engine with a pair of high-pressure cylinders added, it has a num-



ONE OF THE WORLD'S FAIR WORTHINGTON PUMPING ENGINES.



THE PUMPING ENGINE AT PAWTUCKET, R. I., BUILT BY THE CORLISS STEAM ENGINE COMPANY, PROVIDENCE, R. I.

ber of peculiar features. The water cylinders are of the ordinary Worthington pattern, and are placed on one pier of the foundation. Next to the water cylinders, and connected with them by cast-iron cradles, are the high-pressure cylinders, whose piston rods are coupled directly to the plungers. The high-pressure piston rods carry crossheads.

From the outer end of these, two rods extend back to the low-pressure cylinders, resting on expansion plates, placed on the other pier of the foundation. The intermediate cylinders are between the high and low-pressure cylinders and are connected with the high by short, cast-iron cradles, merely allowing sufficient space for the removal of the high-pressure and intermediate pistons. The connection between the intermediate and low-pressure cylinders is by means of a double or intermediate head, containing a sleeve, through which passes a rod, joining the intermediate piston with the low. In this way the power of the intermediate cylinder is transmitted through the low-pressure piston rods, which pass outside of the high and intermediate cylinders to the crosshead on the high-pressure piston rods, and the power of all three cylinders acts, in a straight line, directly on the plunger rod.

The great advantage of this arrangement lies in the accessibility of the steam pistons, each of which may be examined or removed by simply taking off one steam cylinder head and without disturbing any other part of the engine, while at the same time the length of the steam end exceeds but little the combined length of three cylinders. The steam valves are of the semi-rotative cylindrical pattern. The high-pressure cylinders are fitted with cut-off valves by which means a considerable range of steam expansion may be obtained, even in low duty engines. By applying the Worthington high-duty attachment, however, the number of expansions and consequent economy of the machine may be greatly increased, official tests having shown duties of over 130,000,000 foot-pounds per 1000 pounds of steam by Worthington engines thus constructed. The engines are fitted with a jet condenser having an attached or an independent air pump, or a Worthington surface condenser may be placed in the delivery, or in the suction main, using the water pumped by the main engine for condensing the steam. The plungers may be fitted with composition rings or they may work in stuffing boxes. In fact, modifications may be made in the design to suit a great variety of conditions. Although this type of Worthington engine has been on the market for but a limited period, having only recently been patented, several are already in use for water-works service in this country and Europe.

It seems only proper before concluding this article to direct attention to the illustration on the opposite page representing a pumping engine, which, though built nearly twenty years ago, has not yet been surpassed in economy by any two-cylinder compound engine running. It is the famous Pawtucket (R. I.) water-works engine, and was built by the Corliss Steam Engine Company, of Providence. It is of the horizontal, cross-compound type with 15 and 30⅛-inch steam cylinders and 10.52-inch water cylinders, the stroke being 30 inches. It is rated at 140 horse-power and runs at a speed of 50 revolutions per minute. Test figures have shown the steam consumption in this engine to range from 13.681 to 14.041 pounds per indicated horse-power per hour with steam jackets in use, while without the jackets the consumption ran up somewhat higher, reaching 14.256 pounds. The engraving makes a detailed description of the engine quite unnecessary, giving one, as it does, a very clear idea of the principal features of the design.

WROUGHT-IRON TUBE MAKING.

By R. T. Crane.

ABOUT the time of the invention of illuminating gas, in the latter part of the seventeenth century, the long war between England and France was drawing to a close. It had created a great demand for gun barrels, which were largely made at Wednesbury, England, and at its close it left a large amount of this stock on the market, which, with no other demand for it, was used as small gas tubing by screwing the small end of one tube into the large end of another. This supply apparently covered the demand for small tubes for some time and the larger ones were made in the same manner.

In order to understand the invention of gas tube welding it is necessary to describe the welding of gun barrels. This, as outlined by the author in a paper read some time ago before the Master Steam and Hot Water Fitters' Association, consists in taking a properly prepared piece of iron of the right dimensions, drawing the edge down thin, heating it, then rounding it up until the edges lap one over another. In this form it is called "skelp." It is heated in a forge fire, a few inches at a time; then a bar of iron is put on the inside, to give support to the iron while it is being hammered down on the outside and the weld made. It will be seen that only a few inches could be welded at each heating of the iron, making the process a very slow one, and the barrel, when the welding was completed, was left in a very rough and unfinished state.

It appears, from the best information we can get, that about the year 1825, and in order to meet the largely increased demand for gas tubing, it became evident that some better mode of manufacturing gas tubes should be sought for than the process of welding gun barrels. James Russell, in company with his brother John (who had been gun barrel and gas tube makers at Church Hill since 1811), appreciating this fact, set about making an improved gas tube. He concluded that it should be of a uniform thickness of iron, and also, as the pressure of gas was merely nominal, that there was no necessity of so strong a weld as that of the gun barrel. He conceived the idea, and patented it, of welding his tube by butting the edges of the iron together instead of lapping, as in the case of the gun barrel. This invention was a great step in advance of this art, and enabled him to make his tubes much more cheaply and rapidly, and also of vastly superior finish. Still, compared with a later process, a description of which will follow, this production was very slow, as he was obliged to heat and weld it only a few inches at a time, after the manner of welding gun barrels.

To make this gas tubing complete, it was necessary to have a device for connecting pieces of pipe, as the method employed in the case of the gun barrels was not practicable in this case, the iron being of uniform thickness. He now invented the socket, which is a short piece of pipe with a thread on the inside to fit a corresponding thread on the outside of the gas tube, the pipe being screwed in each end of the socket, thus making any desired length of pipe. The effect of this improved process was to so cheapen and beautify the article as to greatly increase the demand for it, and it seems that the invention made a great sensation in England. But this particular process of manufacturing must have been very short lived, it being patented in January, 1825, since it was followed by the patent of Cornelius Whitehouse in February of the same year for butt-

welding tubes by drawing them through a die. This method of welding tubes being brought to the attention of James Russell, he saw its importance, bought it, and immediately proceeded to manufacture his tubes under this patent.

Mr. Russell recognized the principle of the strength of a circle—that is, when the iron for a tube is rounded up any amount of pressure may be brought to bear on the outside without danger of collapsing the iron, and this pressure was necessary to force the edges of the iron together in making the weld. His process of doing this was to heat a small piece of the iron, then place it between two semi-circular dies smaller than the iron, which necessarily forced the edges together, thus making the weld.

To return to the Whitehouse patent, and to make clear the principles involved in it, it may be stated that it takes such dies as Russell used, makes one end of them bell-shaped and fits them in a pair of tongs. He then takes a piece of the rounded-up iron, called "skelp," and puts about half its length in the furnace, heating it to the welding heat. The die is then pressed on the iron, and by means of an endless chain the iron is pulled through the die. The die being smaller than the iron crowds the edges together, thus making the weld.

The principle involved in the Whitehouse method consists in the manner of applying the pressure to produce the weld; that is, he produced it by drawing the iron through the die, and Russell by compressing the dies. So, to give proper credit for these advances in the art, it should be said that Russell is entitled to the credit of discovering that a tube with a butt-weld is sufficiently strong to stand all ordinary pressure, and that a sufficient pressure can be brought to bear upon the circle of the iron to produce the weld. Mr. Whitehouse is entitled to the credit of discovering that the pressure to produce the weld can be obtained by drawing it through the die, which is simply an improvement upon the principle that Mr. Russell discovered; yet it was an invention of very great importance, as it enabled him to make tubes a hundred-fold more rapidly, and also of a superior weld and much longer. Strange to say, this process has never been improved upon, and this is the one in universal use for the manufacture of the small tubes at the present time. The result of the Russell and Whitehouse improvements is the production of an article of great utility at an exceedingly low cost. As an evidence of the importance of the advanced process of Russell and Whitehouse it may be stated that they paid as much for welding the gas tubes under the gun barrel principle as the finished, vastly superior product, is being sold for to-day.

The above-mentioned events took place in the early days of gas engineering, and while steam engineering was also being developed, it had not, up to this time, reached any great degree of magnitude. But its importance began to be more particularly recognized in connection with the building of railroads and locomotives, and through the discovery by Stephenson of the tubular boiler. This created a demand for a larger and different line of tubes, for which the butt weld was not adapted, as the tubes were required to be much larger and stronger in the weld.

It was evident that the only way to produce an iron tube suitable for these demands was to make it with the lap weld, as in the case of the gun barrel, and while it would have been possible to make lap-weld tubes of uniform thickness and moderate length by the methods employed in gun barrel making, it is evident that the process would have been too slow and expensive in operation, and the product too limited in length to meet the demands of steam engineering.

At this time—which must have been in the neighborhood of 1830 or 1835—the Messrs. Russell appeared to have appreciated the importance of manufacturing a new line of tubing, and set about making the machinery necessary for it. To accomplish this was quite a

different task from that of producing the butt-weld tubing, as it called for the highest order of mechanical skill and ingenuity, and there is no doubt that it cost the Messrs. Russell a large amount of money in experimenting before they perfected their machinery. They must have met with untold difficulties and annoyances in perfecting the machinery and furnaces, which only persons who have gone through similar ordeals, though having the benefit of their experience to commence with, can appreciate. They were certainly men possessing extraordinary courage and perseverance to contend successfully with apparently insurmountable difficulties.

About this time, or a little later, Martin Jones commenced experimenting in the same line. He also encountered many difficulties, exhausting his own and his wife's fortune, and in order to save something from the wreck, placed his invention in the hands of a friend, who betrayed him, appropriating it to his own use, improved it by continued experiments and patented it in his own name. He then took into partnership with him two gentlemen of large means, named Lindsam and Bowers, of Birmingham, where they established their works and produced the tubes on a large scale, there appearing to be at once a great demand for them. It is said that this purloiner of the "Jones" idea received for it during many years more than $100,000 royalty annually.

The difference between this and the Russell process appears to be only that Jones made use of four rolls in the welding machinery and Russell only two. The firm of Lindsam & Bowers, who were working under the Jones idea, brought suit against Russell for infringement of their patent, which developed into a bitter contest, involving the expenditure of $2,500,000, and resulting in victory for the Russells.

The process of lap-welding is as follows : The sheet of iron is rolled to the desired thickness, width and length. The edges are then scarfed, as in the case of the gun barrel. It is then drawn, while red hot, through a bell-shaped die, by means of an endless chain, which rounds it up and laps one edge over the other. The whole length is put in the furnace and heated to the welding heat, afterward pushed out of the furnace at the opposite end into grooved rolls of a size corresponding to the size of the pipe. The inside lap is supported by a ball attached to a long bar of iron which holds the ball in position in the roll. The ball and the iron and the groove of the roll all correspond, so that the roll exerts a sufficient pressure upon the iron and the ball to force the laps of the iron firmly together, thus producing the weld.

The entire process must be perfect in order to insure success ; that is, the bending and lapping of the iron, the heating of the furnace and the adjustment of the rolls and balls must all receive the most scrupulous attention.

After the process of welding, the crude piece of pipe is passed through other rolls to give it the correct diameter, and again through others for the purpose of straightening it.

If the tubes are to be used in boilers they are only cut off to the desired length and tested, being then ready for use. If the tubes are to be used for steam pipe, the ragged ends are cut off, screws cut on both ends and a socket put on one end. The tubes are then tested and are ready for the market.

Probably the production of no other line of goods has ever created such a sensation as this, and never were manufacturers so harassed by pirates in the trade as were the Russells. It is a satisfaction to know that they successfully combatted all oppression and were successful in maintaining their patent, and that finally success crowned their enterprise, invention, skill and perseverance. The firm conducted business for many years, through different combinations of the Russell family, under the name of the Crown Tube Works, Wednesbury, England. As to the magnitude of their business, it is stated that in 1824 they made but 3000 feet of tube, while in 1871 the number of feet supplied by the same firm reached the enormous figure of 6,700,000.

THE LIFE AND WORKS OF SYMINGTON.—1764–1831.

By William Fletcher.

IN studying the lives of many of our engineering ancestors we meet with a sad repetition of struggle, hardship, and want. It can be easily understood that the career of most of them must have been an uphill fight with constructive difficulties. Years were spent in single-handed combat with their mechanical problems, the path being paved with blighted hopes and endless delays; yet they bravely scaled every obstruction until success was eventually achieved. But no sooner had their inventions been perfected than keener trouble overtook them, arising from the ridicule and opposition of those from whom they expected support and encouragement, resulting in pecuniary distress, under which not a few were completely crushed.

Oliver Evans, for example, after pleading for months to gain the right to make his high-pressure engine, had his schemes condemned by the friends from whom he had expected encouragement. For years Evans traveled from place to place with his drawings, and failed to find a single person willing to help him to put his ideas into practice. Richard Trevithick was a genius who sowed his inventions broadcast, and impoverished himself in order to satisfy the public of the practicability of his railway locomotive and other engines. The machines made with Trevithick's own hands were used as models by his contemporaries, while he failed to find a single friend among those who were benefited by his works. His last days, in fact, were spent in absolute want, and a collection was made among his fellow-workmen to defray his funeral expenses. Richard Roberts, a most prolific inventor of later times, was forgotten by all who used his machine tools, and was left to fight with poverty unaided.

The subject of this paper was similarly rewarded in his efforts to introduce an invention of undoubted advantage to the community. William Symington had no money of his own to work upon, and he was unable to find a pecuniary helper, owing to which the latter part of his life was spent in privation as one of the waifs amidst the vast wealth of London. Symington was born at Leadhills, in Scotland, in 1764. His father was a practical mechanic and millwright, who superintended and kept in repair the engines and machinery of the Lead Mining Company at Wanlockhead, where one of the Boulton & Watt engines was used for pumping. Young Symington was placed under his father's tuition, and carefully trained in the North Country workshop, where he gave early proof of his mechanical ability. At the age of twenty-one he is said to have conceived the idea of applying the steam engine to the propul-

HULLS' STEAM BOAT, 1736.

LEADHILLS, SCOTLAND. SYMINGTON'S BIRTHPLACE.

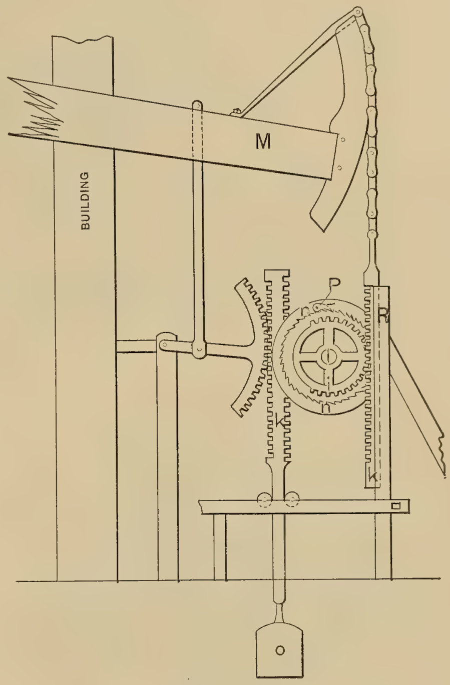
sion of carriages on ordinary roads. He was not long in putting his ideas into a practical shape, for in the year 1786, with the help of his father, he had succeeded in completing a working model of a road locomotive. James Watt, hearing of the construction of this engine, wrote a threatening letter to Symington, warning him not to proceed with the steam carriage, as "the sole privilege of making steam engines by the elastic force of steam acting on a piston, with or without condensation, had been granted to Mr. Watt, and also that, among other improvements, he had particularly specified the application of the steam engine for driving wheel carriages in a patent which was taken out in 1784." Watt's letter appears to have had little effect on the young inventor. It was well known that Watt's specification, which related to wheel carriages, was defective. Watt acknowledges that the wording of his claim was "only intended to keep other people from similar patents." Not only that, but Watt had no faith in steam carriages; he could not construct one himself, and he appears to have been determined that no one else should.

In the same year that Symington had finished the locomotive, Watt said to his partner: "Let such as Symington and Sadler throw their time away hunting shadows." Symington's shadow was a tangible reality which worked so well that those who saw the machine expressed very favorable opinions respecting it, so that the difficult problem of moving carriages on the highway by steam power appeared to be within measurable distance of being solved, and Symington was warmly urged to carry his experiments to a practical issue. Mr. Meason, the manager of the lead mine, was so pleased with the model, the merit of which principally belonged to young Symington, that he gave him letters of introduction to the professors of the Edinburgh University and other scientific men in the city, in the hope that they might lead in some way to his future advancement in life. Moreover, Mr. Meason allowed the model to be exhibited at his own house, invited many persons of distinction to inspect it, and liberally offered to defray any expenses which might be incurred in carrying the invention out in practice. The state of the roads, and the difficulty which at that time existed of procuring water and fuel, afforded sufficient reasons to induce Symington to conscientiously abandon the scheme, which through these causes, he feared, would have produced only disappointment to his kind advisers.

In June, 1787, a patent was granted to Symington for a steam engine on principles entirely new. A circular,

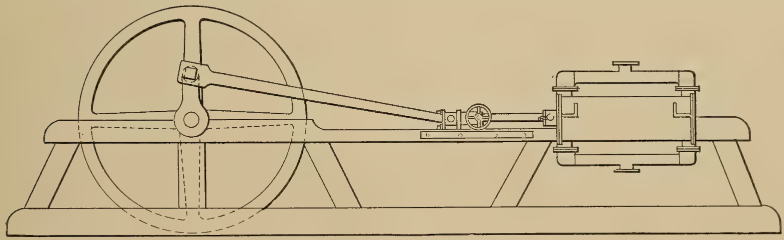
published by the inventor, contained, among other things, the following: "Mr. Symington, having been equally attentive to saving of fire and increase of power, obtained these ends by a simple construction and method of condensing the steam, so that at each stroke a perfect vacuum is produced; and any person acquainted with the old fire engine may easily manage and keep this one in repair. By a trial made between the Watt engine and this one at the Wanlockhead mines, both engines having a cylinder of three feet diameter, consuming the same quantity of coal, and working an equal number of strokes a minute, Symington's engine did at least one-fifth more work than Watt's engine." In this specification of 1787 Symington shows his method of obtaining rotary motion from a steam engine by chains and ratchet wheels. The annexed sketch of the arrangement shows a portion of the engine beam, *M*. Two ratchet wheels were placed upon the shaft to be turned in such a manner that when the engine turned one wheel forward, the other was reversed without impeding the motion or diminishing the power, and was ready to carry on the motion by the time the first wheel was reversed. The ratchet wheels were turned by two rack rods marked *K*, *K*.

Symington's model road locomotive, in which a similar arrangement is applied, is also shown here. It consisted of a carriage with a locomotive behind, supported on four wheels. A cylindrical boiler was used for generating steam, and communicated by a steam pipe with the two horizontal cylinders, one on each side of the fire-box of the boiler. When steam was turned into the cylinder, the piston made an outward stroke; a vacuum was then formed, the steam being condensed in a cold-water tank placed underneath, and the piston was forced back by the pressure of the atmosphere. The piston

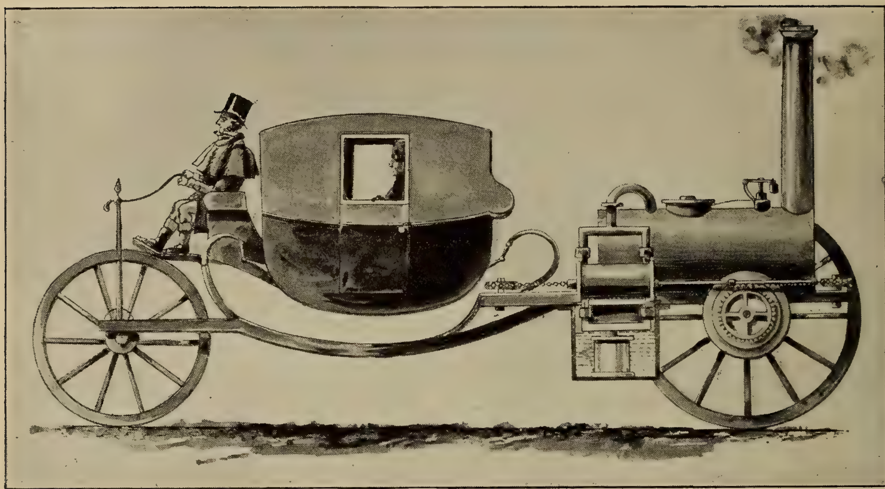


SYMINGTON'S METHOD OF OBTAINING ROTARY MOTION, 1787.

rods communicated their motion to the axle and driving wheels through rack rods, which worked toothed wheels placed on the hind axle on both sides of the engine, and the alternate action of the rack rods upon the tooth and ratchet wheels, with which the drums were provided, produced the rotary motion. Symington stated that an advantage obtained by the method here employed of applying the power of the engine was that it always acted at right angles to the axle of the carriage. Considering the early date of the invention,



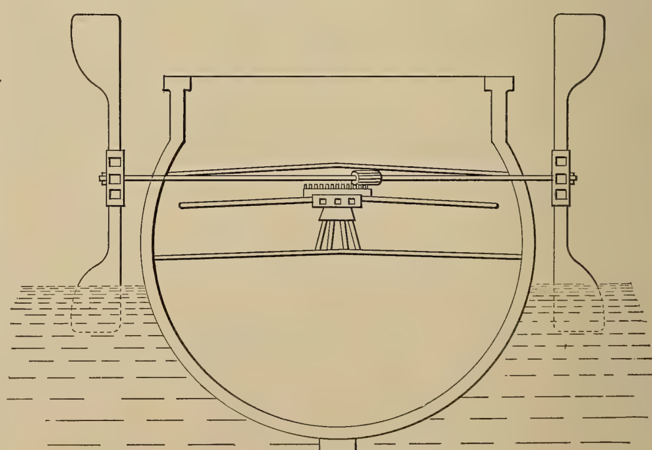
SYMINGTON'S ENGINE, 1801.



SYMINGTON'S MODEL STEAM COACH, 1786.

the arrangement of the locomotive displayed much ingenuity. Symington's road locomotive was allowed to slumber, never to have an awakening, while the inventor turned his attention to the propulsion of vessels by steam.

Before proceeding to Symington's boat engines, however, it may be interesting to briefly name one or two of the earlier proposals having the same end in view. The employment of paddle wheels worked by animal power for the propulsion of vessels is of very ancient date. It is said that the boats by which the Roman army under Claudius Caudex was transported into Sicily were propelled by wheels moved by oxen. In many old books galleys are shown with paddles instead of oars, worked by oxen, horses, or men. An English writer, as far back as 1578, says: "And furthermore, you may make a boate to go without oares or sayle, by the placing of certain wheeles on the outside of the boate, in that sort, that the arms of the wheeles may goe into the water, and so turning the wheeles by some provision, and so the wheeles shall make the boate goe." Papin in 1681 proposed to use the steam engine for propelling a vessel against the wind, and so supersede the labor of rowers and galley slaves. In 1696 Savery obtained a patent for his new invention for "rowing ships with greater ease and expedition than has hitherto been done by any other means." The annexed sketch of his arrangement shows a paddle wheel placed on each side of the ship to be worked by men turning a capstan.



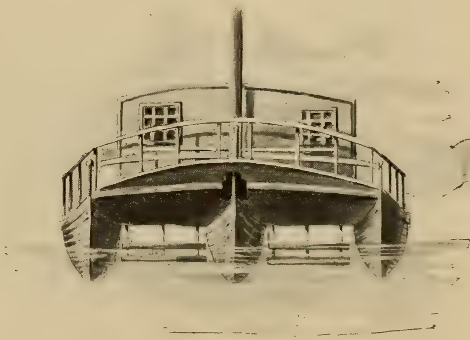
SAVERY'S PADDLE BOAT, 1696.

Jonathan Hulls obtained a patent in 1736 for his "machinery for carrying ships and vessels out of any harbor or river against wind and tide, or in a calm." Hulls' mode of obtaining a rotary motion was ingenious, but it could not have been practically useful. Hulls' description in a pamphlet, issued in 1737, of his method of driving his paddle wheels is so lengthy that we cannot spare the space to describe it. It may be mentioned, however, that he proposed to use poles to reach to the bottom of shallow rivers, and force the vessel along by means of suitable machinery. It is doubtful whether Hulls ever proceeded beyond printing a description of his project. Tradition says, however, that he made a model which he tried on the river Avon, but with such ill success that the engine was removed. A local poet commemorated his failure in the following lines, which were remembered long after his steamboat experiments were forgotten :

Jonathan Hull,
With his paper skull,
Tried hard to make a machine
That should go against wind and tide ;
But he, like an ass,
Couldn't bring it to pass,
So at last was ashamed to be seen.

Patrick Miller, Esq., of Dalswinton, Edinburgh, who had made a large fortune as a banker, after his partial retirement from business devoted much of his time to useful purposes, the improvement of agriculture being perhaps his chief occupation, and one in which he achieved considerable success. He was one of the largest shareholders of the Carron Iron Works, near Stirling, and his improved guns for the Royal Navy were constructed there. In 1787 Mr. Miller published a book on the subject of propelling boats by means of paddle wheels turned by men, in which he gave full particulars of some experiments which he had made with them. This antiquated system of propulsion was revived by Savery ninety years ago, and had been repeatedly tried and abandoned. Miller's method of applying this power was less successful than some of the means employed in the ancient boats. The pamphlet describes double and triple-hulled vessels with paddle wheels. Miller had caused a triple vessel to be built for the sole purpose of improving naval architecture. Alexander Nasmyth, the father of James Nasmyth, who was a landscape painter and an excellent mechanic, put all Miller's ideas into a workable state, and made the beautiful drawings of the vessels which are embodied in the pamphlet.

Some experiments were made with a double vessel put in motion by his water wheels, worked by a capstan of five levers, each five feet long. The gearing was so proportioned that one revolution of the capstan produced three and a half revolutions of the paddles. The vessel was three-masted and sailed well, and when the sails were taken in, five men at the wheels caused her to proceed against a gentle breeze at the rate of about three and a half miles an hour. In a calm, the same number of men caused her to go at the rate of about four and a half miles an hour. After these, and some other experiments not mentioned here, Miller frankly stated that unless he could apply a more powerful agent than the men he employed, his invention would be of little use.



MILLER'S TRIPLE BOAT, 1787. THE PADDLES ARE SHOWN BETWEEN THE HULLS.

Mr. James Taylor now comes upon the scene, and we will allow him to explain his connection with Mr. Miller. He says : "In the autumn of 1785, I went to live in Mr. Miller's family as

preceptor to his two youngest sons. I found him to be a gentleman of a very speculative turn of mind. He was engaged in experiments upon shipping, and had built several vessels upon different constructions, and of various magnitudes. The double vessel seemed to fix his attention most. In the summer of 1786, I attended him repeatedly in his experiments at Leith, which I then viewed as parties of pleasure and amusement. But in the spring of 1787, I had occasion to alter my views respecting the nature of these trips. Being then young and stout, I took my share of the labor of the wheels during one of these experiments or 'pleasure trips,' which I found to be very severe exercise." In fact, the men who worked the capstans, after a short turn at the task, were thoroughly exhausted.

SYMINGTON'S FIRST STEAM BOAT, 1788.

Mr. Taylor repeatedly urged Mr. Miller to apply the steam engine for working the paddle wheels, but the latter was opposed to the idea, having had no experience with steam engines. Mr. Taylor, however, constantly returned to the subject, until Mr. Miller gave way, and asked him to make a sketch showing how the engine could be applied to the paddles. Several methods were portrayed, at sight of which Mr. Miller said: "Well, when we go to Edinburgh we will apply to an operative engineer, and take an estimate for a small engine, and if it is not a large sum we will set about it; but as I am a stranger to the steam engine, you shall take charge of that part of the business, and we will see what we can make of it." Some time afterward Taylor was desired to find an engineer to carry out the work.

It so happened that Taylor had made the acquaintance of Symington, and had seen the steam engine work to which reference has already been made. He also witnessed an interesting trial of the model locomotive on the floor of Symington's house, and was pleased with it, because it appeared to him to be very suitable for Miller's purpose. Symington came to Edinburgh that winter to attend some educational classes. Taylor mentioned Miller's schemes to him, and asked if he would undertake to apply his engine to the vessel. This he engaged to do, and Taylor accordingly recommended Symington and his engine to Miller. It was finally arranged that the experiment should be performed on the lake at Dalswinton, in the ensuing summer of 1788.

Accordingly, in the spring, after the classes at the college broke up, Taylor remained in town to hurry the castings, which were made in brass, by Geo. Watt, founder, back of Shakspeare Square, to Symington's drawings and under his personal directions. When the parts were finished they were sent to Dalswinton, where Symington erected the engine, at about the beginning of October. The engine was mounted on a frame, and placed upon the deck of a very handsome double pleasure boat upon the lake. Taylor says: "We then proceeded to action, and a more complete, successful, and beautiful experiment was never made by any man at any time, either in art or science." The cylinders were only four inches in diameter, yet the vessel moved at the rate of five miles an hour. It should also be noted that the hull of this first steamboat was constructed of tinned iron plates. It was therefore the first iron steamboat.

Mr. James Nasmyth in his autobi-

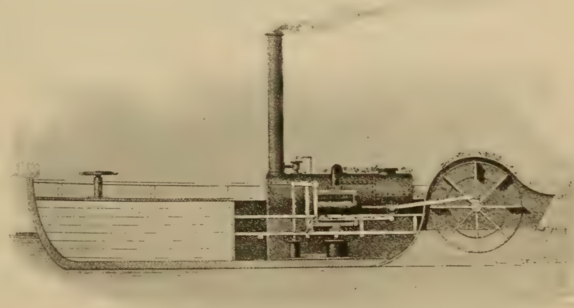
ography says: "This, the first steamer that ever 'trod the water like a thing of life,' the herald of a new and mighty power, was tried on the 14th of October, 1788. The vessel steamed de-

THE CHARLOTTE DUNDAS, 1803.

lightfully, at the rate of five miles an hour, though this was not her extreme rate of speed. The persons on board consisted of Patrick Miller, William Symington, Sir William Monteith, Robert Burns (the poet, then a tenant of Mr. Miller), James Taylor and Alexander Nasmyth. There were also three of Mr. Miller's servants, who acted as assistants. On the edge of the lake was a young gentleman, then on a visit to Dalswinton. He was no less a person than Henry Brougham, afterward Lord Chancellor of England. The assemblage of so many remarkable men was well worthy of the occasion. Taking into account the extraordinary results which have issued from this first trial of an actual steamboat, it may well be considered that this was one of the most important circumstances which ever occurred in the history of navigation."

The illustration on the opposite page is from a sketch by Mr. Alexander Nasmyth of this first steamboat and her remarkable crew. The original drawing of the steamer is now in the gallery of the Museum of Naval Architecture at South Kensington. For several weeks the steamer continued to delight Miller and his numerous visitors. On the approach of winter, the engine was removed from the boat, and placed as a sort of trophy in his library at Dalswinton, and while there, Taylor made a drawing of it and its mode of connection with the paddle wheels. This also is here reproduced. The engine is now carefully preserved at the Patent Museum at South Kensington.

After the experiments recorded above the following account of the trip appeared in the Dumfries newspaper, and was subsequently inserted in The Edinburgh Advertiser of October 24, 1788, and in Scots Magazine for November of the same year: "The following is the result of an experiment no less curious than new. On the 14th inst. a boat was put in motion by a steam engine upon Mr. Miller's piece of water at Dalswinton. That gentleman's improvements in naval affairs are well known to the public. For some time past his attention has been turned to the application of the steam engine to



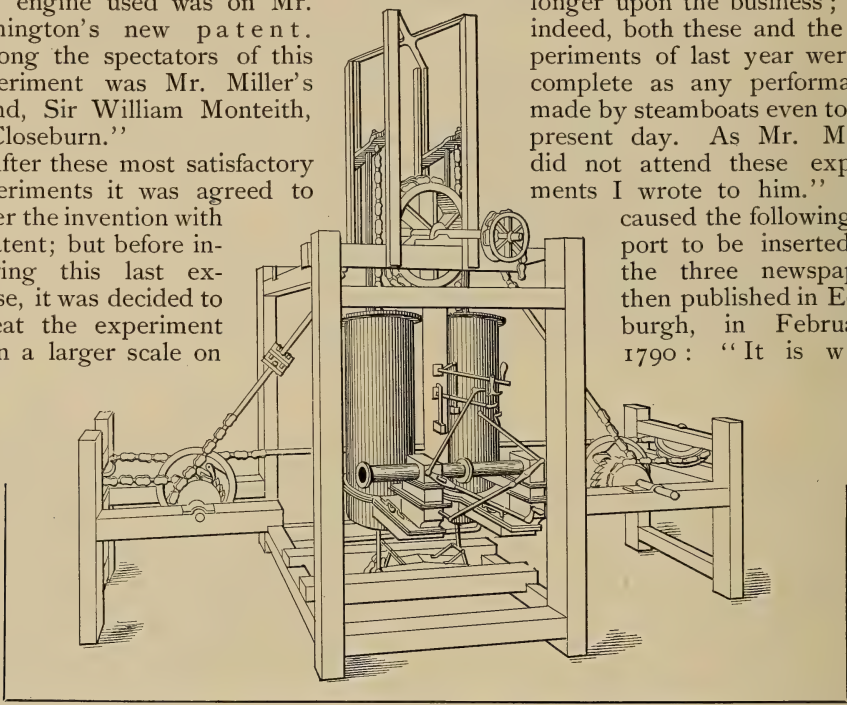
MACHINERY OF THE CHARLOTTE DUNDAS, 1803.

the purposes of navigation. He has now accomplished, and evidently shown to the world, the practicability of this, by executing it upon a small scale. A vessel twenty-five feet long, and seven

feet beam, was, on the above date, driven with two wheels by a small engine. It answered Mr. Miller's expectations fully, and afforded great pleasure to the spectators present. The engine used was on Mr. Symington's new patent. Among the spectators of this experiment was Mr. Miller's friend, Sir William Monteith, of Closeburn."

After these most satisfactory experiments it was agreed to cover the invention with a patent; but before incurring this last expense, it was decided to repeat the experiment upon a larger scale on the Forth and Clyde Canal, and to construct the engine at Carron. Accordingly, in the spring of 1789, Mr. Taylor and Mr. Symington went to Carron, and the latter constructed a double engine, each cylinder being eighteen inches diameter. In November the vessel with the machinery was launched into the canal, and proceeded slowly and pleasantly for some time; but when the engine was put to full speed, the paddles, which had been made as light as possible for manual power on Miller's principle, began to fail, the floats breaking off, thus spoiling this experiment. New paddles of a stronger type were soon fitted, and the experiment was repeated without accident, the steamer moving at the rate of nearly seven miles an hour. On the following day the experiment was equally successful, the steamer working most satisfactorily.

Mr. Taylor says: "Satisfied now that everything proposed was accomplished, it was unnecessary to dwell longer upon the business; for, indeed, both these and the experiments of last year were as complete as any performance made by steamboats even to the present day. As Mr. Miller did not attend these experiments I wrote to him." He caused the following report to be inserted in the three newspapers then published in Edinburgh, in February, 1790: "It is with great pleasure that I inform you, that the experiment conducted on the great canal with a vessel built formerly for a different purpose, propelled by a steam engine, has lately been repeated with great success. The velocity acquired was up to seven miles an hour. This sufficiently shows, that with a vessel properly constructed, a velocity of eight to ten miles an hour may be easily accomplished, and the advantages of so great a velocity will be sufficiently evident, as there can be few winds, tides, or currents, which can easily impede or resist it. Every well-wisher to the extension of arts and commerce must be highly gratified with the signal success of this important experiment." Miller had the steamboat dismantled; the engine was taken to the Carron Works, and the boat laid up at



SYMINGTON'S FIRST BOAT ENGINE, 1788.

Bruce Haven. It will be noticed that Miller paid little attention to the later experiments with the larger steam engine, as his thoughts were busily engaged in a new enterprise, and his connection with navigation suddenly terminated. Taylor accepted another situation, hoping to return to the steamboat business in case Miller should be inclined to move in the matter. But agricultural pursuits took such hold of Miller that no other object could withdraw him from them. If Symington's efforts had ended there, he would have been justly entitled to honor. His engines had propelled a steam carriage on land, and were successfully applied to the first steamboats that carried passengers in Great Britain at a fair rate of speed.

We lose sight of Symington for the next thirteen years, during which time he was by no means idle; but none of his objects could be carried out on account of his lack of funds. As soon as monetary aid was forthcoming, he once more appeared on the scene. In 1801 a patent was granted to him for a new mode of constructing steam engines, and applying their power to the purposes of producing rotary motion, without the interposition of a lever or beam. In this invention there was a horizontal cylinder with steam acting on both sides of the piston, working a connecting rod and a crank. Lord Dundas, of Kerse, who was an extensive proprietor of property in the Forth and Clyde Canal, employed Symington to make a series of experiments on steamboats, with the view of supplanting the horses employed to draw the vessels on the canal. The result of these experiments was the production of the first practical steamboat, named the "Charlotte Dundas," in honor of his Lordship's daughter. Symington employed his new horizontal steam engine to drive the paddle wheels, and by keying the crank arm direct to the paddle axle, he combined, for the first time, those improvements which constitute the present system of steam navigation.

THE SYMINGTON MEMORIAL AT LEADHILLS.

During one of the experiments with this steamer, Symington took on board Lord Dundas, the Hon. George Dundas, R. N., Arch. Spiers, Esq., and several other gentlemen; and after having attached to the steamboat two other vessels, each of seventy tons burden, named the "Active" and "Euphemia," he towed those vessels to Port Dundas, Glasgow,—a distance of nearly twenty miles,—at the rate of three and a quarter miles an hour. During the trial it blew so strong a gale right ahead during the whole day that no other vessel on the canal attempted to move against the wind. Proofs having been given of the efficiency of the vessel to supersede horses for towing, proposals were made to the proprietors of the Forth and Clyde Canal to adopt it. It was feared, however, that the waves produced by the steamer would injure the banks of the canal, and the proposal was therefore rejected. Lord Dundas, however, entertained a more favorable opinion on the subject, and called upon the Duke of Bridgewater for the purpose of recommending the adoption of Symington's steamboat. His Grace at first appeared to doubt the utility of the invention, but after

having seen a model of the vessel, and received explanations from Symington, he gave him an order to build eight boats, similar to the "Charlotte Dundas," to ply on his canal.

Symington returned to Scotland, elated with the prospect of being able to introduce steam navigation in a short time, and to realize to himself the advantages which his ingenuity and unwearied perseverance gave him reason to anticipate ; but he was doomed to disappointment, for on the same day that he was informed by Lord Dundas of the final determination of the committee not to allow steamboats to be employed on the canal, he received intelligence of the death of the Duke of Bridgewater. Unable longer to struggle against these misfortunes, his resources being exhausted, he was obliged, with great reluctance, to lay up his boat in a creek of the canal, near Brainsford drawbridge, where it remained for a number of years exposed to public view.

It is important to remember that the "Charlotte Dundas" did not cease to run on account of any disablement ; she was not stopped through any failure of the machinery, but solely on the supposition that the waves produced by the paddles would injure the banks of the canal. This vessel might, from the simplicity of its machinery, have been at work up to the time of Symington's death, with such ordinary repairs as are required by all steamboats. It is very interesting to note that stern wheel steamers, with horizontal engines placed on the deck, coupled direct to the paddles, exactly the same as Symington's latest boat, are now made by several celebrated firms for shallow river navigation.

After the death of the Duke of Bridgewater, fortune appears to have run steadily against Symington, and his later years were completely wasted in vain attempts to induce capitalists to befriend him, and canal companies to make a trial of his boats. A few years before his death he presented a memorial to the Lords of the Treasury, in consequence of which the sum of £100 was awarded him from His Majesty's privy purse, and a year or two afterward a further sum of £50 per annum was allowed, but he did not live long to enjoy it. He died in March, 1831, and was buried in the churchyard of St. Botolph, Aldgate, where, Dr. Smiles says, "there is not even a stone to mark the grave of the inventor of the first practicable steamboat."

In the summer of 1890 a Symington memorial was unveiled at Leadhills, the birthplace of the ingenious Scotchman. It is a polished granite shaft, thirty feet high. On the back and front are inserted bronze medallions, the front being a portrait medallion of Symington ; underneath is the inscription : "William Symington, the inventor of steam navigation. Born 1764 ; died 1831. Erected by public subscription." Sixty years were thus allowed to elapse before a monument was erected in memory of a man whose invention has had so marked an influence upon maritime progress.

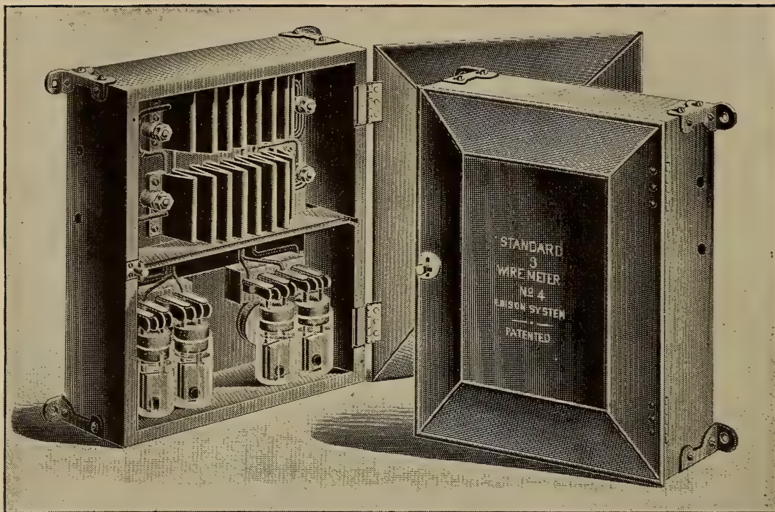
HOW ELECTRICITY IS MEASURED.

By A. E. Kennelly, F. R. A. S., Vice-Pres. Am. Inst. El. Engrs.

IS IT not strange that while we know so little of what electricity consists, of what it really is, that our application of its power should already be so general, and that this power, or in a certain sense electricity itself, can be furnished, bought, and sold like any material commodity. The measurement of electrical supply is, however, quite a latter-day accomplishment, being practically a development of the last decade, for prior to 1880 there existed no electrical distribution of electric light or power to measure. Within this brief period about one hundred thousand electrical meters have been constructed in the United States. This number comprises very few distinct types, for, notwithstanding the fact that several hundred different kinds of meters have been devised and tried, only a very limited number have come into extended use. The law that apportions survival unto the fittest has been active in this branch of invention and industry, and the ranks of the survivors have been reduced to certain well-defined species. The recognition of these types, of their special advantages and of their course of evolution, forms an attractive theme to even the most superficial observer, and a world of investigation to the more deeply interested student.

Turning for a moment from electric meters to the electricity by which they are operated, it has to be remembered that all the existing electrical conveniences supplied by wires into houses are, excepting telephonic communication, delivered as energy. If the electricity be supplied for driving a motor in the house, the performance is evidently an amount of mechanical work such as would be represented by raising a given mass of matter through a certain height, and capable, therefore, of being reckoned in foot-pounds. Or, if the electricity be employed for culinary purposes in an electric stove, the supply can be rated at the amount of water which would be raised through a given range of temperature by all the heat electrically developed, this water heating being also capable of expression in terms of mechanical work. Again, less obviously, but no less certainly, if the electricity be supplied to incandescent lamps, it is heat once more, expressible in foot-pounds, that is developed in the carbon filaments, raising their temperature to that of brilliant incandescence. To supply motors, stove, or lamps, electric generators in the supply stations have to be revolved against magnetic forces by steam engines, and hungry furnaces under their boilers must be fed with the coal which is our present great stock of petrified solar energy. Were our methods and machinery of transformation and transmission ideally perfect, the sum total of all the foot-pounds delivered in the houses would equal the heat known to be latent within the coal consumed. Under the best working conditions, there is an enormous disparity between the sides of this balance-sheet. Heat streams off and leaks everywhere, through boiler walls, chimneys, pipes, valves, cylinders, journals, and electric wires, so that, of the theoretical energy in coal, less than ten per cent. is available to the consumer in heat or motive power under the conditions of recognized good practice, but it is the duty of the meter to record and indicate the amount of electrical delivery, in terms of energy or in terms of some proportional quantity, from which the energy can be directly deduced.

Just as in the case of the delivery of hydraulic power, where the energy is jointly proportional to the volume of



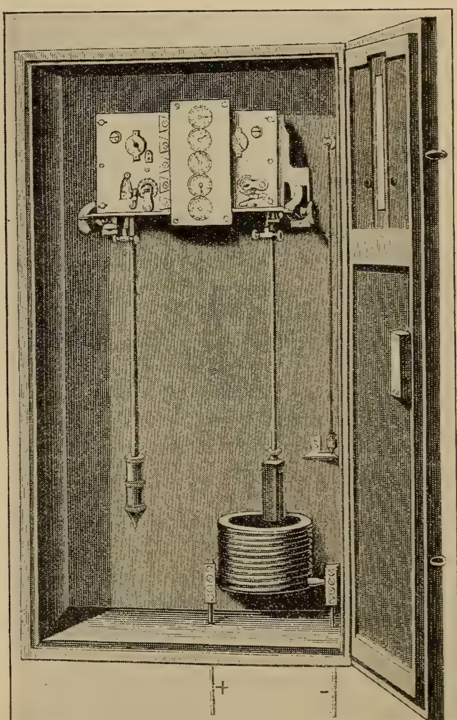
THE EDISON CHEMICAL METER.

water and to the pressure at which it is delivered, so electrical energy is jointly proportional to the quantity and to the electrical pressure or voltage of supply. The commercial unit of quantity is the ampere hour, universally adopted, and is the quantity of electricity which would be supplied in one hour by a constant current of one ampere. The product of the current strength supplied in amperes, and the pressure of supply in volts, gives the rate of energy-delivery in watts, of which 746 are equivalent to Watt's standard horse-power of 33,000 foot-pounds exerted per minute. A sixteen-candle power incandescent lamp will take, say, half an ampere at a pressure of 100 volts, representing an energy of fifty watts, or about one-fifteenth of an electrical horse-power, and in one hour the energy consumed in the lamp would amount to fifty-watt hours. The commercial unit of electrical energy is the kilo-watt hour or 1000 watt-hours, approximately equal to 1⅓ horse-power-hours. It is clear that a lamp will absorb the same fifty watt-hours of energy per hour if supplied by half an ampere at 100 volts, one ampere at fifty volts, or two amperes at twenty-five volts, and broadly, the three lamps so constructed from homogeneous carbon would give an equal amount of light. Since, however, the greater the current, the larger must be the wire that shall convey it with equal facility, it becomes economical to employ high-pressure lamps of small current consumption, up to the point at which the filaments can with difficulty be prepared, and practical distribution of lighting is never carried out below fifty volts pressure.

Although every electrical supply meter is thus fundamentally an energy registering device, and as such its rate of recording should be proportional to both volts and amperes, yet most of the meters in use are constructed to record amperes only, at a definite pressure of supply. These are ampere hour indicators and are actuated only by the quantity of current supplied through them. Were the pressure not uniform, their indications might be far from representing the proportional actual delivery of power. It happens, however, that nearly all systems of electrical distribution include incandescent lamps upon their circuits, and the incandescent lamp is most sensitive to pressure. A lamp that will give sixteen candle-power at its normal pressure of, say, 115 volts, will probably give nineteen at 118, and thirteen at 112 volts. In

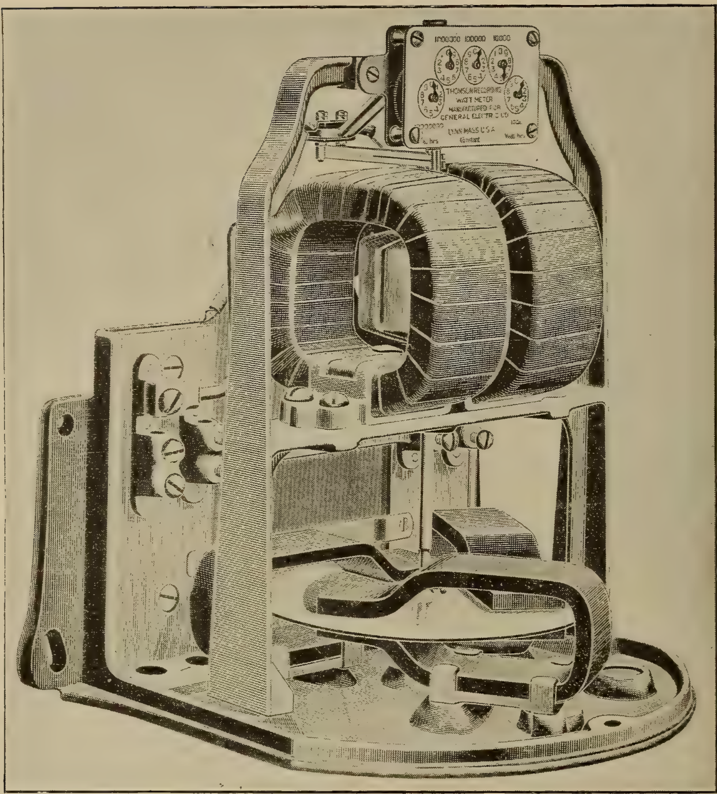
the former case it is forced in illumination to the great abridgement of its natural term of life ; in the latter, there is a feebleness of illumination that is sufficient indication of defective pressure. In order, therefore, to maintain an efficient service, the pressure of delivery has at all times to be carefully regulated. It is this circumstance that renders the amperemeters available.

There are three distinct types of meter, operating by entirely different principles. These are the electro-chemical meter, the clockwork meter, and the electromotor meter. Meters of the electro-chemical type were devised and employed by Edison in 1881. They depend upon the fact that in an electroplating bath the rate of depositing metal is exactly proportional to the strength of the electric current passing through it. An interior view of one of these meters is shown on this page. The two corked glass bottles are the electro-plating baths, and in each two plates of zinc are kept immersed at a definite distance apart, in an aqueous solution of zinc sulphate. These plating baths are too small to allow the full current of supply to pass through them, so that an arrangement has to be made by which a definite fraction of the whole current shall traverse them; the remainder being carried by the convoluted metal strips fastened in the upper part of the case, as shunts to the bottles. The resistance offered by the strips to the current in comparison with that offered by the branch circuit, including the bottle, is such that a certain exact number of milligrammes of zinc is transferred from one plate to the other per ampère-hour delivered through the meter, according to its size and capacity. Once a month the bottles are withdrawn and replaced by others freshly prepared. After the zinc plates have been dried, they are carefully weighed, and the weight of zinc transferred from one plate to the other during the month determines immediately the total supply during that time in ampere hours. For simplicity and precision this meter has never been surpassed. It has no moving parts, subject to wear or derangement, and the only sensitive portion of the instrument is the bottle, which is periodically replaced. An incandescent lamp, not shown in the illustration, is sometimes placed between the two bottles, for the purpose of heating them should the meter be placed in some cellar exposed to severe frost and where the solution in the bottles might become frozen. As soon as the temperature within the meter falls to a dangerously low point, a composite strip



THE ARON METER.

or bar of two different metals, riveted side by side, is warped by their uniform contraction into contact with the tip of an adjusted screw, bringing the lamp into circuit with the mains. In a few minutes the heat generated by the lamp warms the air within the case to a temperature well above that at which the solution in the bottles can congeal, the screw and expanding composite strip then part company, and the lamp goes out.



THE THOMSON RECORDING WATT-METER.

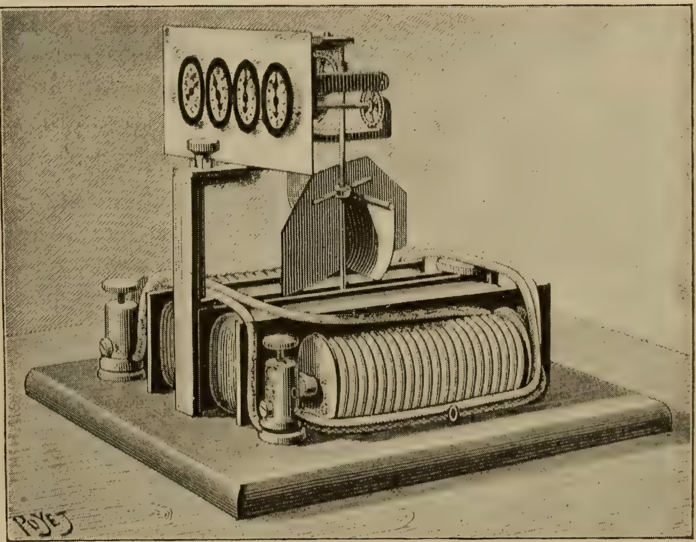
Although the electro-chemical record of this meter is admitted on all sides to be reliable, it is open to the objection that the consumer has no means of reading that record or keeping check upon its development. The meters that have since been developed have been devised with a view to meeting this want. Dial recording meters, operated by clockwork, have been made in a variety of forms. The clockwork train runs continuously and is wound up by an inspector at his periodical visits. When no electricity is supplied through the meter, the clock runs freely, but as soon as a current flows through the instrument, communication is established by electro-magnetic mechanism between the clockwork and the dial, in such a way that the rate of communicating movement to the dial depends upon the rate of electrical delivery. The dial then preserves the sum of all such transferences.

One of the best known instruments of this type is the Aron meter. It consists of a clock driving two pendulums, side by side, at the same normal rate. The pendulums are in communication, through a differential train of wheelwork in such a way that, so long as they keep pace, no movement is delivered to the dial wheels, but if one pendulum is retarded or accelerated, the dial train commences to operate at a rate proportional to the change. This accelerating influence is exerted by making the bob of one of the pendulums an iron bar, which swings close above a fixed coil of wire carrying the main supply current. The electro-magnetic attraction of the coil upon the bob increases with the current of supply and acts like a reinforcement of gravitation, dimin-

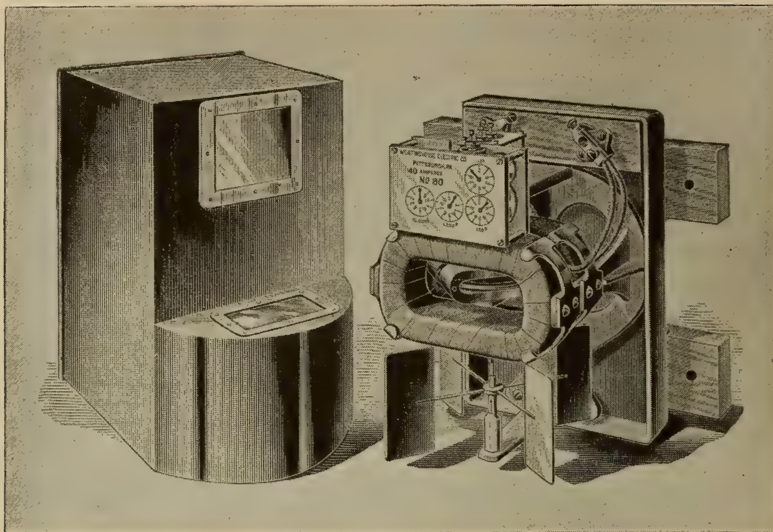
ishing the period of vibration. This meter has maintained a good record for reliability, but is somewhat delicate and complex in construction.

In the third type of meter, the current supplied through the instrument drives an electro-magnetic motor at a speed proportional to the rate of delivery. A dial, geared to the motor shaft, keeps the record of the number of revolutions made on a scale corresponding to commercial units and duly marked off on the counter. Such an instrument dispenses with the necessity of regularly winding up a driving spring, and is as entirely automatic in its action as a gas meter. A very common size of such meters has a capacity for supplying thirty incandescent lamps. It has, therefore, to start when the first lamp is turned on, and its duty is to accelerate regularly for each successive lamp brought into circuit up to the full number, assuming that each lamp takes the same amount of current or energy.

Two of these motor meters are in very general use. The illustration on this page shows the interior of the Thomson recording watt-meter. The name watt-meter implies that the instrument does not merely record ampère-hours, but registers the supply of energy by responding to variations both of current and pressure. The instrument consists of a delicate electro-magnetic motor, whose armature shaft is vertical. The only iron or steel in the meter is for purely structural purposes, in the shaft and external framework, for while iron in the magnetized parts of a motor enormously augments its power, it becomes difficult to keep that power proportional to the exciting current strength. The armature shaft turns upon a jewel in the base plate, and the only friction that it sustains outside the bearings, is exerted by delicate brushes of metal strip, resting on a narrow commutator fixed near the upper end. A feeble current, passing from the mains continuously through the armature and a resistance at the back of the instrument, keeps the armature magnetized with an intensity directly proportional to the pressure of supply. No movement of the armature can result, however, until current is delivered through the two large fixed coils of wire that overhang and cover the armature, corresponding to the field coils of an ordinary motor. The magnetic force which these exert upon the already magnetized armature is directly proportional to the strength of the supply current, and tends to rotate the armature round its axis. The magnetic action of the armature being thus proportional to the pressure of supply, and the magnetic action of the field coils to the supply current, the rotatory



THE PACCAUD-BOREL METER.



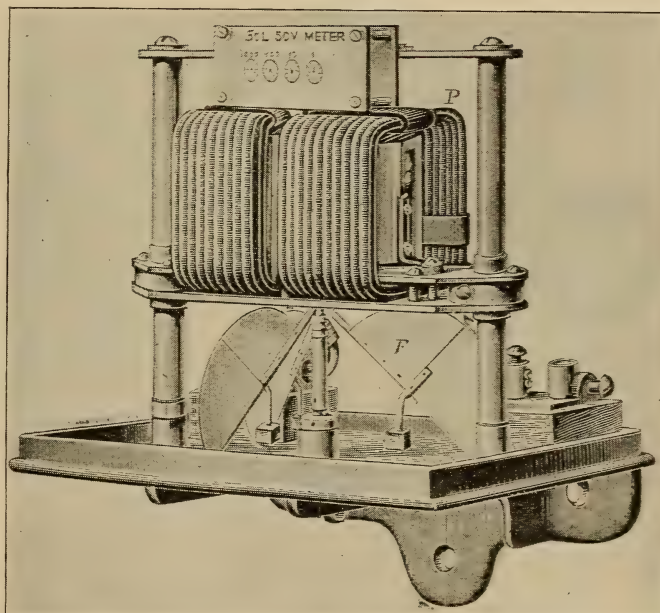
THE SHALLENBERGER METER.

impulse is directly proportional to their product, or to the rate of delivering energy, and the speed of rotation being made proportional to this impulse, the dial train will register the energy delivered.

In order to ensure a rate of rotation proportional to the rotary impulse or couple, a load, or resisting couple, has to be provided which is strictly proportional to the speed. This requirement is filled by a copper disk, attached to the shaft near its lower extremity, and rotating in a horizontal plane between the poles of three, fixed, permanent horse-shoe magnets attached to the baseplate. As these magnets are not in contact with the disk, they can oppose no friction to its starting from rest. As soon as rotation commences, however, the conducting disk, moving between the magnet poles, acts like a dynamo armature revolving between the poles of a field magnet, and currents are generated in the disk in eddies around each edge of each magnet. There are thus six stationary electric whirls or vortical currents in the plane of the disk which supports and yet travels through them.

These whirls are attracted by the magnet poles above them, just as coils of wire would be in the same situation when carrying currents of like intensity, and the electro-magnetic force so exerted acts like a brake or drag upon the copper disk. The more swiftly the disk spins, the stronger are the eddy currents induced in its substance, and consequently, the resisting couple exerted upon the disk is strictly proportional to its speed. It is thus a brake acting upon the armature, not through the gross contact of substance, but through the invisible chains of magnetic flux that extend through air and copper between the poles of the permanent magnets. At the upper end of the shaft the moving force is magnetically delivered through the air between the fixed coils and armature ; at the lower end there is the automatic magnetic brake. For houses that are supplied on the three-wire system,—the lamps being divided into two groups which are operated in series, yet independently,—the fixed or field coils are divided, the right hand coil being included in one circuit, and the left hand coil in the other, so that the speed or rotation is due to the combined current supply in both circuits. By this means one meter performs the work for two circuits. The advantages of the

Thomson meter are that it can be employed for both alternating and continuous current circuits, that it is dial-recording, and has a good record for accuracy. Its disadvantage is that it constantly expends about five watts in the feeble current magnetizing the armature. This amounts to an energy expenditure of about forty-four kilowatt-hours in the course of a year. It has been proposed to employ an electro-magnetic switch which shall break the armature circuit when the last light is turned off, and so save about three-fourths of the average daily leak, but the device has not yet come into general use.



THE SLATTERY METER.

Another well known instrument of the motor type, but exclusively employed on alternating current circuits, is the Shallenberger meter. The interior of this meter is represented on the preceding page. A vertical, light shaft of steel wire, pivoted on a jewel, carries, about half-way up, a little horizontal disk of iron which serves as the armature. Surrounding, but out of contact with, this disk is a grid of copper supported diagonally, and outside the grid again are two coils of insulated wire carrying the supply current. The passage of an alternating current through these coils produces within them an alternating magnetic field, that is to say, a magnetic field through the coils, reciprocating from right to left, and back again from left to right, about 260 times a second. The first effect of this oscillating magnetism is to penetrate the copper grid and generate alternating currents round this grid, a pulse of current to each reciprocation, just as in an alternating current transformer. The induced grid currents are almost out of step with the supply currents, so that when the former are just about to change direction, the latter are at full flow, and *vice versa*. The grid currents also develop their own local magnetic field. At the position occupied by the disk-armature there are thus two separate reciprocating magnetic forces in action, one across the supply coils, the other diagonal to this and across the grid, but the two components are "in quadrature," or just out of step. It is well known that two independent simple reciprocating motions inclined, and in quadrature to each other, compound into an elliptic motion, and the resultant field near the disk does not reciprocate, but revolves elliptically 130 times a second. The effect of the double set of reciprocating fields is as though a magnet were suspended over the disk and set revolving elliptically in a horizontal plane. This revolving magnetic field causes the iron disk armature to follow, either by magnetic lag in the iron, or by eddy currents, or by both

actions combined. The moving force is proportional to the square of the supply current strength. In order that the rotation of the armature should be proportional to the current strength simply, it is necessary that the resisting force should be proportional also to the square of the speed. This is accomplished by the four rotating fan blades carried on the lower part of the shaft. It is an experimentally determined fact that up to the speed at which viscous slip occurs, the resistance to the motion of a revolving fan blade in air varies as the square of its speed. Suitable gearing connects the armature shaft with the dial wheels whose pointers mark off ampère-hours, the voltage of supply being assumed constant and regulated to the lamps on the circuit.

All dial recording electric meters are necessarily delicate in construction owing to the existing conditions of distribution, for at their full capacity of delivery they may not absorb more than two per cent. of the supply pressure on the premises, and since they are called upon to commence registration at a load of from two to five per cent. of their full capacity, the amount of energy left available for operating the dial mechanism at the starting current can only be feeble. Their accuracy has also to be reasonably high, for if they should commonly over-register, the customers would soon detect the error and insist upon their removal, and if they should underindicate, they might convert the margin of profit in an electric system into a positive loss.

The introduction of meters into electrical distributions has also an influence upon commercial metrology. However serviceable the yard, gallon, ton, acre, bushel, horse-power, and fluid ounce have been during the history of the Anglo Saxon race, they are now generally admitted to belong to an incoherent and needlessly complex system of measurement. An international system of weights and measures has in later times been developed on a more scientific, practical, and convenient basis of matter and notation. Slowly the old order of things gives place to the new. Even now the official standard of length adopted by the United States is the distance—one metre—between two marks on a standard metal bar kept in France. Electricity being the most modern form of commercially distributed energy has taken the impress of modern thought and progress, so that its meters spread a tendency to superannuate the standard horse, and to popularize a decimal notation.

JOHN HENRY HARRIS.

By Ernest S. Cronise.

JOHN HENRY HARRIS, whose death occurred on the 22d of January last, was for many years and up to the time of his death one of the most conspicuous figures in the engineering business, both in this country and England, having, for twenty-five years, been identified with pushing the introduction of the direct-acting steam pump; and the almost universal adoption of that type of pump is owing very largely to his remarkable energy and zeal in this direction.

Mr. Harris was born in Troy, New York, January 4, 1838, being a direct descendant of Patrick Henry and Roger Williams, from whom he inherited the many characteristics which were so marked in him. He was educated in Vermont and at Springfield, Mass., with the intention of entering Yale College, but this was abandoned, and at eighteen years of age he went to sea, making several voyages to China and Japan. On the last return voyage he was shipwrecked on the Nova Scotia coast, narrowly escaping death by drowning, being rescued by fishermen

who provided him with food and shelter until he was able to start for his New England home. An interesting fact connected with his shipwreck was that, though losing all of his personal effects and being thrown into a heavy sea, he clung to a small bag which contained a Bible given him by his mother and a package of love letters from the young lady who afterward became his wife.

He arrived in New York on June 4, 1861, finding everything in a state of bustle and excitement on account of war having been declared. His patriotism and love of the sea prompted him to enlist at once, which he did, entering the Navy as a volunteer. He was assigned to the U. S. S. Albatross by the Commandant of the New York Navy Yard on June 26, 1861, and immediately entered upon active service. While attached to the Albatross he participated in the battle of Port Hudson and in the numerous skirmishes and minor fights on the Mississippi during the spring of 1863 until detached from the ship in June of that year. He was on the Powhattan when Richmond was taken, and served with Farragut, Porter, Lee and Dupont in the North and South Atlantic and East and West Gulf Squadrons. He was in both battles of Newport News. In July, 1863, he was ordered to the U. S. S. Vicksburg and participated in the usual minor actions of the blockade. In October, 1864, he was instructed to take charge of the prize steamer Hope with thirty-four men and report to the proper authorities at Boston. He afterward rejoined the Vicksburg, and in December was transferred to the Keystone State. While on this ship he participated in the capture of Fort Fisher. In September, 1865, he was detached from the Pembina, to which he had been transferred, and was granted leave of absence until honorably discharged on January 18, 1866. He was urged to enter the regular service but declined, and took up the study of law under Senator Hoar in Worcester during the years 1866 and 1867. Finding the routine work unsuited to him, and irksome, he engaged in mercantile business, filling several positions with more or less success.

His first connection with the pump business was when he was given charge of the New York office of the Geo. F. Blake Manufacturing Company, and the way in which this was brought about was somewhat interesting and indicative of the energetic manner in which he afterward forced himself into a prominent position in this line of business. Previous to being engaged by the Blake Company, he was selling feed-water heaters or some apparatus of like nature, and happening to drop into the Blake Company's Boston office, engaged Mr. Blake in conversation with a view to selling him one of his heaters. In this he was successful, and after having left, Mr. Blake turned to a gentleman who was there at the time, with the remark that that man had succeeded in selling him something that he did not want. A few days afterward the question of selecting a manager for the New York office of the Blake Company was brought up, but at that time there did not seem to be the right sort of man in the employ of the company.

During the discussion the gentleman who had been in the office at the time of Mr. Harris's visit remarked to Mr. Blake: "I know the man you want," and in reply to Mr. Blake's question as to who the man was, this gentleman said: "That young man who the other day sold you something you did not want. If he can succeed in doing that sort of thing, he is the kind of man to put at the head of your New York office." The result was that Mr. Harris was sent for, offered the position, which was promptly accepted, and for many years he had charge of the Blake Company's business in New York and also went abroad for the purpose of introducing the Blake pumps in Europe. Mr. Harris afterward organized the Harris Steam Pumping Company, and was also connected with the Deane Company.

About twelve years ago he became connected with the firm of Henry R.

Worthington, and a little later went over to London for the purpose of enlarging the export business of that firm. The result of this visit was the establishment of the Worthington Pumping Engine Company with branches throughout England, the English Colonies, and the East, a business which has since grown to large proportions, and all of which has been entirely the result of Mr. Harris's energy and push as Vice-President and General Manager. The immense amount of work involved in this, the greatest effort of his life, told on his health and he was obliged to return to this country, but he still retained the general management of the English Company, afterward becoming Chairman of the Executive Committee of Henry R. Worthington, Incorporated, which position he held at the time of his death.

Mr. Harris was a member of the Institute of Mechanical Engineers of Great Britain, the Naval Architects, and the Society of Arts, London. He was also a member of the American Society of Mechanical Engineers, the Loyal Legion, and of the Engineers', Lawyers' and other clubs in New York. Personally he was an extremely popular man, enjoying a wide and numerous acquaintance among engineers and engineering firms in the United States, England and on the continent. He was of a warm and generous disposition and possessed the esteem and attachment of those with whom he was brought in contact. One of his most noticeable traits was the great interest he took in young men, particularly those with whom he was connected in business, many of whom have reason to gratefully remember his words of encouragement and kindly interest at times when they were most needed. Although for two years a very great sufferer from a disease which was beyond all possible skill and for which no hope could promise relief, he bore himself like a true soldier to the last, still retaining his interest in all the details of the business with which he had been connected, and up to the last giving evidence of the tireless energy and indomitable will which had made him the foremost man in his line and had pushed the Worthington interests in all parts of the known world. How thoroughly he was appreciated by the firm of Henry R. Worthington, is indicated, in a measure, by the following memorial resolutions which were adopted by its executive committee :

"It seems fitting that the Executive Committee of Henry R. Worthington, of which the late John H. Harris was Chairman, should record its appreciation of his services and express its high estimate of his character, its respect for his memory and its sorrow at the severance of the personal ties which bound him to us.

"He was earnest of purpose, honest of heart, strong in his convictions, sincere in his friendships and manly in all his relations. He was possessed of sound practical judgment and vigorous common sense, combined with untiring energy and devotion to the interests of this company, with which he was so long connected. Knowing the springs of human action and studying the motives and relations of men, he was sagacious and intelligent in his methods and most successful in the accomplishment of his purposes. His integrity was unquestioned and his private character above reproach. He endured the martyrdom of a fatal disease with a quiet and heroic fortitude which evoked the sympathy and admiration of all who knew him. He has left the record of a life full of usefulness, well spent and honorable.

"This Committee, in behalf of Henry R. Worthington, the welfare of which was the object of his pride, and to the success of which his efforts materially contributed, deeply regret the loss of his zealous support and valuable counsel, and we desire to record on our minutes this tribute to his memory, and to tender to those more near him our sincere condolence and profound sympathy."

ALTERNATING ARC LIGHTING FOR CENTRAL STATIONS.

By H. S. Putnam.

THERE are many arc lamps for use on alternating incandescent circuits which have been placed on the market during recent years to meet the growing demand for them. To make a successful alternating arc lamp, however, there are several difficulties to be overcome. These, as summed up by the author in a paper recently read before the Northwestern Electrical Association, are that the mechanical parts of the lamp must be so constructed that no vibration producing a noise can be set up in them by the alternating current ; then, again, a carbon must be produced which can be easily volatilized by the current, enabling the arc to be maintained and, at the same time, to burn steadily ; and, finally, the hum in the arc itself, produced by the alternating current, should be overcome, or at least reduced.

The many advantages in using the alternating arc light for both municipal and commercial purposes are readily apparent. Simplicity, flexibility and uniformity in the style and size of the machinery are essential to the convenient and economical operation of a central station. A multiplicity of machinery, belts and dynamos not only consume an excessive amount of power, but are also expensive to maintain. The number of machines in a station should be reduced and their size increased as much as possible consistent with an economical handling of the load. By using the alternating arc lamp the necessity of a separate dynamo for arc lights is entirely done away with. Many of the stations in the smaller towns can furnish their entire current for all purposes with one machine. If for economical load reasons this should not be desirable, the dynamos can be made interchangeable and used on any circuit. In the larger stations, instead of having a dynamo and circuit for every 50 or 60 arc lights, there is practically no limit to the number of lights that can be placed upon a single circuit and operated more conveniently and much more economically than with the direct current arc system. The large saving in power, cost of maintenance and operating expenses effected by this simplification of machinery is readily apparent.

In the line of construction, there is the same economy and simplicity united also to a greater convenience and smaller first cost. Arc and incandescent lights can be furnished from the same circuit and transformer. Arc lights of any desired candle power can be used, and if desirable charged for at meter rates. The lights are entirely within the control of the consumer, and can be turned on by him when needed. The very large saving thus effected by not being obliged to run all the arc lights and circuit, as is customary at present, to accommodate a few who desire their lights earlier than the balance, would in itself make a very nice dividend in some stations, to say nothing about the satisfaction it is to a customer to be able to have his light when he wants it.

If it is necessary to have any considerable number of lights, such as street lights, under control at the station, this can be very easily and economically accomplished by dividing one wire of the circuit, placing the arc lights between one of these wires and the common return for them both. The return wire, of course, should have a cross section equal to the sum of the other two, and the two latter should be proportioned to the loads they have to

carry respectively. By means of a switch, this arrangement places the street lights, or any other circuit, entirely under control from the station, takes no more copper, eliminates converter losses when the circuits are not turned on, and in most cases will effect a saving of from 40 to 50 per cent. in the first cost of the line construction, as compared to the ordinary arc system.

There is the further gain in this system that both arc and incandescent lights can be furnished at any place along any of the circuits. Usually in smaller cities, and in large ones as well, the incandescent circuits are run only to the main business portion of the city, while the arc circuits form a net work, practically covering the town. The business in the outlying districts is so scattered that it does not usually pay to run an incandescent or commercial arc circuit to catch it. With the system under consideration, however, every circuit in the city, wherever located, is available for either arc or incandescent lights and for motors also. The amount of scattered business that can be thus picked up would aggregate in many towns to as much as is furnished in the business portion proper, and could be supplied at but a slightly increased expense.

There are several methods of connecting the lamps in the circuit. By far the best and most economical, of course, is to use a special transformer reducing the voltage from 1000 or 2000 to 30 volts. These can be made of various sizes to run any desired number of lights. The ordinary 50 volts transformer can also be changed to give the necessary 30 volts, by tapping a third wire on the secondary wire in the transformer at such a point as to give the required voltage. Another method is to use a small transformer, transforming from 50 or 100 volts, as the case may be, to 30 volts. This is a very nice method for commercial use, when both arc and incandescent lights are wanted in the same store or building, and avoids the necessity of the third wire that must be used in the last mentioned method. On 100 volt circuits an automatic regulating coil may also be used running three lamps in series. With this coil, one, two or three lights can be run, as desired, and the energy consumed is proportional to the number of lights burning. The four wires necessary in this method is somewhat of an objection. Lastly, the voltage can be cut down by the introduction of resistance from 50 to the 30 volts desired. This, however, is not to be recommended, excepting in special cases, on account of the loss of energy.

Another important consideration is the extremely low voltage at which these lamps are operated and the consequent freedom from danger to life or from fire. The transformer is, of course, placed outside and is not within reach. Only the secondary current is led to the lamps and this only at 30 volts pressure. No special precautions need be observed in insulating the wires or lamps. The lamps can be trimmed and handled with as much freedom and immunity from danger as the incandescent lamps. Street lights can be tested about as freely on wet and stormy nights as on any other occasion and with absolute safety.

The question of the economical working of electric light plants is deservedly receiving a great deal of attention at the present day. The one-machine system is a step forward in this direction. In the station the reduction in the number of dynamos reduces the friction losses materially. Instead of a multiplicity of dynamos, belts and counter-shafting, there is but one machine to look after, only one commutator, one set of brushes, one set of bearings, one armature, and one belt, or better still in a direct coupled machine, no belts at all. The large saving in power and labor thus effected and the increased convenience and economy of such a system needs no argument in its favor.

The alternating dynamos, as is well known, are also of considerably higher efficiency than the ordinary arc dynamos. This united with the use of larger units and the economy in power

mentioned above will make a total saving in many cases from 25 to 30 per cent. in the consumption of power, and consequently in the coal bill.

The first cost of such a plant is less, and the cost of maintenance and depreciation are materially less than in the ordinary systems, where separate dynamos are used for both arc and incandescent lights.

Several of the largest and quite a number of small central stations have already adopted this one-dynamo system of lighting, and the indications point to its very general introduction. It is a solution of many of the difficulties which have attended the operation of central stations, and will commend itself not only to the manager and superintendent, but to the customers and stockholders as well. From one engineering standpoint it unites all the simplicity, flexibility and economy for which we have been striving, giving at the same time the best service for the least money, and for the smallest operating expense. The one-dynamo system is emphatically the system of the future.

Current Topics.

Some of the most successful and remarkable engineering enterprises have been claimed to owe their existence to circumstances which, when considered in themselves, seem far too trivial to have produced such important results. Though opinions be divided as to the first transmission of power by electricity, for example, it has been strenuously maintained in some quarters that accident, pure and simple, was the cause of the great discovery and an interesting story has been told for many years of the attending circumstances. This is to the effect that at the International Exhibition at Vienna, in 1873, the Gramme Company exhibited two dynamo machines for plating purposes. One of these machines was in motion, and a workman who noticed that some cables were trailing on the ground, thinking that they belonged to the second machine, placed them in its terminals. To the surprise of everybody this second machine immediately began to turn, and it was then discovered that the first dynamo was driving the second. It would be strange, indeed, if there were not other versions of this story and, accordingly, we find several somewhat different accounts, from all of which, however, it would appear that the development of any measurable power in a machine taking its supply of

electricity from a primary dynamo was something wholly unexpected and correspondingly startling.

CLOSELY analogous is the narrative of the origin of one of the most successful foundry blowers now in use, according to which the inventor was attempting to construct a water motor which persistently refused to go round when the water was turned on. In the determination to learn what was wrong a belt connection was made with a line shaft so that the motion of the machine might be studied. By the same means a reverse motion was given to it, and the way in which it threw the water, and, after the water had been exhausted, drove a current of air, suggested an entire change of purpose, and the machine was finished and put on the market as a blower instead of as a water motor, and thousands have been built since. The story, often told, with various modifications of detail, serves as an additional illustration of the fact that inventors frequently stumble upon success in entirely unexpected directions.

IT has been very aptly stated that "boilers which can raise steam from cold water in three minutes, can do almost anything else in the next three minutes if they are not closely watched," the implication, of course, being that they are rather suspicious and correspondingly undesirable forms of steam generators. However true this statement may be in a general sense, it would seem to require some qualification in the light of more recent developments in steam boiler design, at least one form of boiler having been brought out within the last few years in which phenomenally quick steaming capacity and safety seem to have been successfully combined. M. Serpollet, a French engineer, the designer of this boiler, recently described its latest modification in a paper read before the Société d'Encouragement, from which it appears that since the generator was first put to practical use, about ten years ago, important changes have been made in its construction which have successfully adapted it to all power purposes for which a boiler may be desired. The chief feature of the boiler is found in the use of a capillary tube resembling an ordinary tube with very thick walls, which has been flattened out so as to transform the passage through it into a very fine, in fact a hair-line, slit. In the earliest design this tube was arranged in the form of a coil through which the water was forced periodically by a pump in just sufficient quantity to generate the amount of steam required at any particular moment. There was practically no water space in the boiler, and what water was forced in was instantly flashed into steam. Very satisfactory performances were obtained with this arrangement, and its compactness and light weight for given powers admirably commended it for a variety of purposes, among them the propulsion of common road carriages. Quite a number of such carriages were, in fact, equipped with this form of boiler and suitable engines, and are today in current use in the streets of the French capital. It was found impracticable, however, to build boilers of this particular design in sizes much beyond about ten horse-power, and their use, therefore, was comparatively restricted.

A SERPOLLET BOILER TUBE.

IN M. Serpollet's latest design the capillary tube has been retained, but instead of being arranged in the form of a coil, it is made in straight lengths, connected in series by suitable bends, running back and forth over the furnace, and arranged in layers or horizontal sections, the number of which may be easily increased or diminished according to the amount of power desired. There is no restriction, therefore, within reasonable limits, to the sizes in which the boiler may be built,

and its range of service is accordingly extended. The tube itself also has undergone some change in form, its cross section now being of inverted U-shape. The working principle, however, remains the same as in the early model, and all the original advantages of quick steaming, light weight, and practical immunity from explosion danger have been retained. One of these boilers forms part of the equipment of a steam car on the lines of the Compagnie des Tramways of Paris, and is said to give excellent results.

RAISING iron and steel to a welding heat by plunging it into a bucket of water is one of the more recent electrical accomplishments which has excited no end of interest and admiration. The phenomenon was illustrated experimentally to thousands of spectators at the Columbian Exposition last year, but instead of being simply an interesting scientific demonstration as it was there regarded, it has latterly been applied in a practical way as an every-day substitute for the time-honored forge-fire. At the Edison Illuminating Company's Pearl street station, at Brooklyn, N. Y., the "water-pail forge," as it has been aptly named, can be seen in daily operation, and the practical value of its astonishing performances has there been demonstrated beyond all doubt. The little sketch which is here given explains the simple character of the outfit better, perhaps, than any words can do it. Across the top of an ordinary wooden water bucket rests a bar of iron to which the negative pole of a dynamo is attached by a wire. The other pole of the machine is connected with a plate of copper in the bottom of the bucket. To bring the end of any desired bar of iron or steel to a welding heat, all that is necessary is to rest it against the bar across the top of the bucket and to dip the point into the water within. This closes the electric circuit, and in a few moments the end of the bar becomes hot enough to be readily worked under a blacksmith's hammer. What actually happens when the circuit is closed is this :—The water in the bucket, under the action of the passing current, immediately begins to decompose into its component gases, oxygen and hydrogen, and the latter adheres in a film to the submerged part of the metal bar, protecting it from contact with the surrounding water. If now the electric current were not very strong it would cease to flow, because of the break in the circuit made by the hydrogen accumulation. With a sufficient strength of current, however, the resistance of the hydrogen envelope is

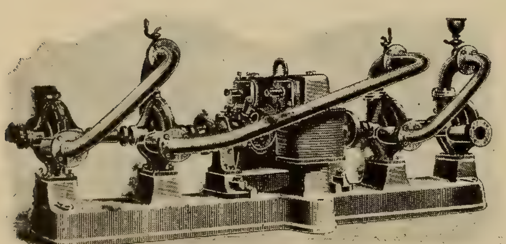
HEATING IRON IN A PAIL OF WATER.

overcome, and in doing this heat is developed,—sufficient in this case to quickly bring the end of the bar to a white heat. That the water does not quench the bar is readily explained by the fact that the hydrogen film prevents the two from coming into actual contact. How great the possibilities of this water-pail forge are can easily be imagined. The ordinary forge and blower, and the necessarily attendant coal and smoke and dust, all are entirely dispensed with, and the whole outfit may be a likely feature of the ideal blacksmith shop of the near future.

WHILE regularity of engine and dynamo speeds is a generally recognized

necessity for incandescent electric lighting systems, it is often assumed that arc lights do not require it. This, however, is a decided fallacy. The resistance of an electric arc varies continually. It is instructive to put a single arc lamp in circuit and then watch the index of an ammeter. This will seldom or never be quite at rest. If the carbon be a bad one, the index will jump through comparatively large ranges, each splutter of the lamp being attended by a jump. When there are a number of lamps in series, a little overfeeding or a little underfeeding of the carbons may considerably alter the resistance, and, unless there be a reserve of power and a good governor, the result will be unsatisfactory. If a little overfeeding take place the resistance will be diminished, the quantity of current flowing will be increased and more load thrown on the engine. If the latter be properly governed, its speed will be kept constant, and the lamps will have a chance of recovering themselves; but if, on the contrary, the speed should fall off, the lamps will get worse and worse.

Centrifugal pumps, connected in series, have, of late, been used in a number of places with apparently satisfactory results, though very little data seem to be available regarding the total efficiency of a pump combination of



CENTRIFUGAL PUMPS IN SERIES.

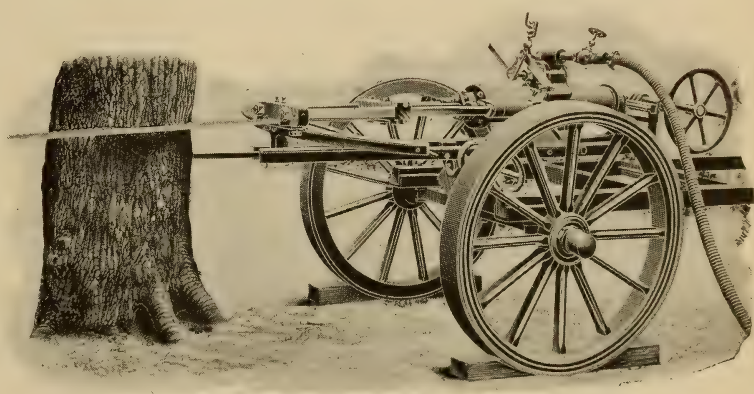
this kind. In one case which has come to notice, four pumps have been coupled in the manner shown in the annexed illustration, and are driven by one electric motor, the whole outfit, which is of French design, being used to raise water through a height of about 157 feet. In another instance, cited by the Lawrence Machine Company, of Lawrence, Mass., two of their 7-inch high-lift pumps are similarly worked in series at the establishment of the Manufacturing Investment Company, at Madison, Me., the pumps being placed on the same level and working against a total head of 40 feet. Again, for irrigating land, at Grand Junction, in Colorado, two 8-inch Lawrence pumps, placed on different levels, however, are used, the second pump being forty feet above the first one, or at one-half the total elevation of eighty feet to which the water is raised. The discharge pipe of the first pump is directly connected to the suction pipe of the second, as in the instances already mentioned. There are, undoubtedly, many other examples of pumps working after this fashion, but in no case that has come to knowledge have any tests been made to determine their degree of efficiency.

Washing air of its impurities by passing it through water screens or through chambers into which water is profusely sprayed, is a well known and much-used process in heating and ventilating practice. Its merits were conclusively demonstrated years ago, and ever since advantage has been taken of them in large ventilating installations in which their expense was warranted, and where a smoky and an unclean outside atmosphere suggested the desirability of submitting the air to some cleansing process before allowing it to pass into buildings. It is not surprising, therefore, that a somewhat analagous method should have suggested itself as of likely service in dealing with the now so much-discussed smoke problem, and that it should have been tried with encouraging results. At any rate, a newspaper paragraph, now going the rounds, tells of its application by an English factory owner whose repeated conflicts with the local smoke ordinance prompted experiments in this direction, and apparently with perfect satisfaction. According to the published description, some-

what indefinite, perhaps, in a few respects, the apparatus used by him consists of a large cast-iron tank, in which is a slotted barrel, which is fitted with perforated beaters, and the tank is partly filled with water. The smoke is drawn into the barrel from the machinery by a powerful fan, and undergoes a scrubbing process. The barrel rotates very rapidly, churning up the smoke with the water. On the top of the barrel are several semi-circular trays or sieves, which are perforated, and effect the purpose of further washing the smoke. The smoke, which escapes from the beaters, is caught by these sieves, and dashed down again by a very fine spray of water from the beaters. The black sludge of solid matter is forced to the top of the chamber, and thrown over into a chute, which conveys it to a wooden tank. The smoke which finally escapes from the machine is said to be comparatively inoffensive, and there is certainly good reason to believe that this should be so.

It is interesting to note, moreover, that the use of the apparatus does not end with the cleansing of the smoke. The black deposit gathered by it is taken off in barrels to be used in the making of paint and printing ink, yielding an acceptable revenue instead of polluting the atmosphere, and the remaining liquid is said to have proved itself a most valuable disinfectant. Thus a two-fold purpose is accomplished, either one of which would seem to be quite sufficient to commend the process to manufacturing communities in which smoke suppression is a live topic.

TREE felling by means other than manual labor has been an engaging subject to many inventors, and for some time past a more or less interesting array of appliances designed to accomplish it has been paraded before the readers of mechanical journals. One of the more recent of these machines, brought out in England by Mr. Allen Ransome, of Chelsea, reminds one very much, in appearance, of the now so familiar rock drill, the drill proper, of course, being supplanted by a reciprocating saw blade, substantially in the manner shown in the accompanying sketch. The piston to which the saw blade is attached works in a cylinder of small diameter but rather long stroke, pivotally supported on a pair of wheels, so that the whole arrangement is readily portable. Steam is intended to be supplied to the machine from a portable boiler through a long steam hose, so that the boiler can remain in one place until the machine has felled all the trees within a considerable circle around it, the space cleared, of course, depending upon the length of the hose. Cutting down a tree, however, is not the only function to which the machine is limited. By partially rotating it on its axis the saw can be set to cut in a vertical direction, or at any angle between the horizontal and vertical positions, so that, after having been felled, a tree may be quickly cut up into desired lengths. It generally happens that when a large tree falls it does not lie flat, as its branches hold the upper part of the trunk from the ground, and in order to



A TREE FELLING AND CROSS CUTTING MACHINE.

squarely cross-cut trees lying in such a position it is necessary to incline the saw somewhat from a direct vertical line. This is readily done by the adjusting capacity just mentioned. Suitable adjustments also are provided to enable elevation or depression of the saw to accommodate high or low-lying trunks, as the case may be. It is not uninteresting to note that Mr. Gladstone, whose prowess as a woodman, in addition to his better known talents, was so widely exploited two or three years ago, has honored the machine with a very favorable comment, being reported to have said, after seeing it in operation, that it would do as much work in a minute as a woodman could do in an hour.

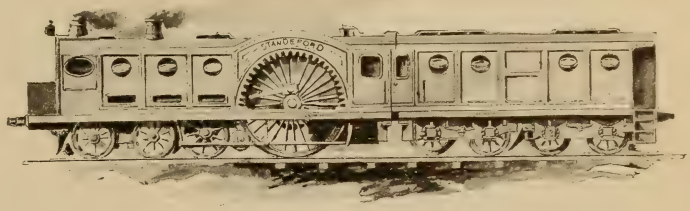
WHAT probably most locomotive builders will regard as a freak of construction has more recently been inaugurated on the Orleans Railroad in France, being a Corliss locomotive design from which great things are expected in the way of fuel economy. The first French locomotive of this type was tried in an experimental way in 1887, and it would seem from recently published accounts in some of the French journals that the results were sufficiently promising to encourage a wider use of the system. Accordingly several other engines were fitted up with Corliss valve gear and at least two of them are now running on the Orleans line in regular passenger service, performing most satisfactorily, it is said, from every point of view. Corliss locomotives, however, do not seem to have endeared themselves to engineers in other countries. In the United States the application of the Corliss principle in this branch of railroad service was probably confined to the historical engine "Advance," built many years ago at the shops of Corliss & Nightingale, at Providence, and run for a time on the Stonington Railroad. In economy of steam, as shown by indicator diagrams, the "Advance" was superior to the existing link motion and lap-valve engines, but the detached, variable cut-off was too delicate an arrangement to endure the jar of such rough service.

THE late Alexander L. Holley, who had served with Corliss & Nightingale when the engine was built and tried, revived his reminiscences of the "Advance" in one of his discourses before the American Society of Mechanical Engineers years ago in the following characteristic words: "'The Old Jigger,' as the locomotive was euphoniously called, had, as nearly as I can remember, three hundred and sixty-five valves, one to break down every day in the year. And as to the valve motion, well, nobody ever counted the number of its pieces. They were as the sands of the seashore. Most of them used to jar off during the first few trips of the week, after which all the men in the shop could comparatively keep track of the rest of them. I will say for the Old Jigger that she made the best indicator card I ever saw from a locomotive; clean cut-off, almost a theoretical expansion curve, and an exhaust as if she had knocked out a cylinder-head. Well, once in a while, after she had been jackassing over the road about four hours behind time, and we had pinch-barred her into the round-house, we used to pull out these indicator cards and talk them over right before her, and we would look at her and ask one another why in thunder an engine that could make a card like that would act as if the very old—chief engineer was in her. And next morning she would rouse up and pull the biggest train that had ever been over the road—ahead of time. But she was an inconstant old girl—and lazy, too,—used to prefer to work with one side, and always made some plausible excuse for breaking down the other."

THE story was told several years ago that a railroad man of wide experience, and who had held important positions, expressed great surprise upon seeing for the first time, after his many years of service, the common method of rolling rails. He said he had supposed

that they were run out in a liquid state into molds and afterward cut off into proper lengths, but that the process of gradual reduction of an ingot of metal in a plastic state by repeated passing between rolls had not occurred to him as being the way in which the work was done. Some of the operations connected with the manufacture and working of metals, however, are of just such a nature as to suggest reasons for the man's view. Castings are made of any reasonable length by running liquid metal into a mold, and lead pipe, as is known, is made by causing the metal to "flow" through a suitable die by the intense effort of a hydraulic press. Many years ago, too, an excellent quality of sheet metal was made by pouring liquid steel between revolving rolls, by which the metal, as it cooled, was delivered on the other side in a quite perfect sheet. More recently, in fact, this method of sheet metal making has been revived and practiced in a measurably successful manner. Other similar, continuously flowing processes are in current use in different lines of manufacture, so that, after all, the railroad manager probably reasoned as closely in his thought upon the subject as any man could from the note which he had made of what he supposed were similar things.

A SALOON express locomotive is what Mr. Michael Reynolds, at one time connected with the London, Brighton & South Coast Railway, in England, calls the rather unique creation with which he has latterly busied himself and with which he proposes to realize abnormal railroad speeds. The designs for the engine are said to have been already put into the hands of a well known firm of English builders, and it would seem quite likely, therefore, that the subject of the annexed little illustration will, before long, assume tangible shape. Thus far, however, very little more than is here shown has been made public about it, and the picture, therefore, must, for the present, be left to tell its own story. The immediately striking feature of the locomotive, of course, is found in the substitution for the usual tender of a close-coupled car, whence the name "saloon locomotive."

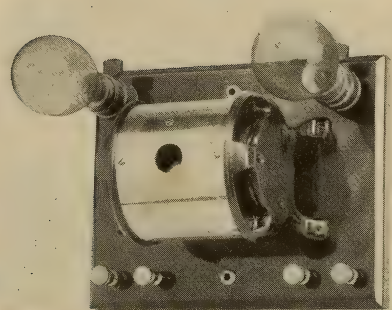


A SALOON EXPRESS LOCOMOTIVE.

WITH the development that has been recorded during the past ten years in the way of electric propulsion of vehicles, it is interesting to recall one of the earlier applications of an electric locomotive of diminutive pattern, made early in the eighties at Milan, Italy, for lighting the large number of gas jets which illuminated one of the streets known as the "Victor Emanuel Gallery." This street was at that time, and probably still is, protected by a glass roof, which included a large dome at a considerable height from the ground, and this, too, was illuminated by gas. To light the various jets a tramway had been laid parallel with the gas-supply pipe, and on this ran a little electric locomotive, such as might have been purchased as a model at some philosophical instrument dealer's shop. This miniature engine carried a spirit sponge lamp, with a burner standing at right angles to its side, and of such length that the lighted wick would pass over the gas jets. With the gas turned on, the engine was started on its journey around the dome, and as it progressed the escaping gas was easily ignited.

WITH the use of alternating dynamos in parallel, a means of determining in a

delicate and yet effective manner the exact point of synchronism in speed and coincidence of phase of two alternators has become a necessity. This has more recently been met in the United States by a neat little device brought out by the General Electric Company, and most aptly nick-named "the growler." It consists simply of a cylindrical iron case, perforated at the side and closed at the ends by flexible diaphragms. Each of these has opposite its centre the pole of an electromagnet, and in using the device one of these magnets is connected in circuit through a transformer, with each of the machines to be run in synchronism. The currents are then passed through the magnet coils, and the diaphragms, in consequence, emit loud, clear notes. As the dynamos approach synchronism, the notes approach closer and closer in period, giving rise to what, in music, are known as sound beats. These gradually grow slower and slower until finally the diaphragms fall into unison and each gives out the same low, clear note. At this moment, which is sharply marked, the switch connecting the two dynamos should be thrown in. Extreme sensitiveness is one of the features of the apparatus, which is claimed to distinctly indicate the small differences from synchronism which even the phase lamp device fails to detect.



THE "GROWLER."

A NOVEL and ingenious use that was made some time ago of a rapid river current in India aptly illustrates the fertility of resource of the average engineering contractor. At a certain point along the river a temporary bridge was urgently necessary for the transport of materials to be used in the building of an important neighboring structure, but the only available material was a quantity of three-inch planking, about ten feet long and a little over three feet wide, and some ordinary round timber cut from a neighboring forest. Pontoons were made of two single planks, placed about fifteen feet apart, each plank being held on edge at an angle of about fifty degrees from the vertical, both inclining up stream, and kept at their proper distance by framing made from the round timber already mentioned. Both pontoons were moored to a chain. The peculiarity of the bridge, of course, was that the water pressure upon the inclined surfaces of the planks, due to the swift current, permitted them to carry a considerable load, and the structure served its purpose admirably, accommodating a pretty lively traffic for an unexpectedly long period.

Very sincerely yours
Edwin J. Houston.

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CASSIER'S MAGAZINE.

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ASCENDING PIKE'S PEAK BY RAIL.

By Albert Spies.

A MOUNTAIN FREAK.

TO Major Zebulon Pike is due the honor of first describing the famous peak which now bears his name and which, for years, has occupied one of the most commanding positions in the scenery of Colorado. It is now nearly a century since Major Pike first beheld the "Great Snow Mountain," hanging on the western horizon like a small blue cloud, and an interesting record is extant of his futile efforts to reach, by a short march, the peak which, under the fantastic tricks of the rarefied atmosphere of the Western mountain-base plateaux, seemed so short a distance off despite the many intervening miles. Days of ceaseless tramping finally brought him near the base of the mountain, but there new and unforeseen difficulties beset him, leading, ultimately, to the conviction that "no human being could ascend to the summit" of that tremendous peak. Since that time stories of its grandeur have grown and spread. Each succeeding year has made it more famous, until to-day there is perhaps scarcely a mountain anywhere more widely known or more talked of.

At its foot rests Manitou, cradled among the hills. Manitou was known to white men long before Major Pike discovered the peak, and descriptions of its famous springs are to be found in the writings of French missionaries who visited the spot more than two hundred years ago. The healthful properties of the waters were familiar to the Indians from time immemorial, and, in grateful recognition of the beneficent characteristics of the springs, they named the place in honor of the Great Spirit, bestowing upon it the musical and significant title which it still bears. Less than fifty years ago Manitou was the haunt of wild and savage animals, and still more wild and savage men, and one cannot but marvel at the contrast of to-day when measured by the admirable portrayal of the scene in its early state, given by George F. Ruxton, an Englishman, who visited the springs in 1847. Ruxton's experiences were novel, interesting, and thrilling. His visit was an incident of a tour from the City of Mexico to Pike's Peak, and he tells in a most striking manner of his penetration into these fastnesses of Nature, untouched by civilization, of his royal revelry in this hunter's paradise, and of his narrow escapes from Indian dangers.

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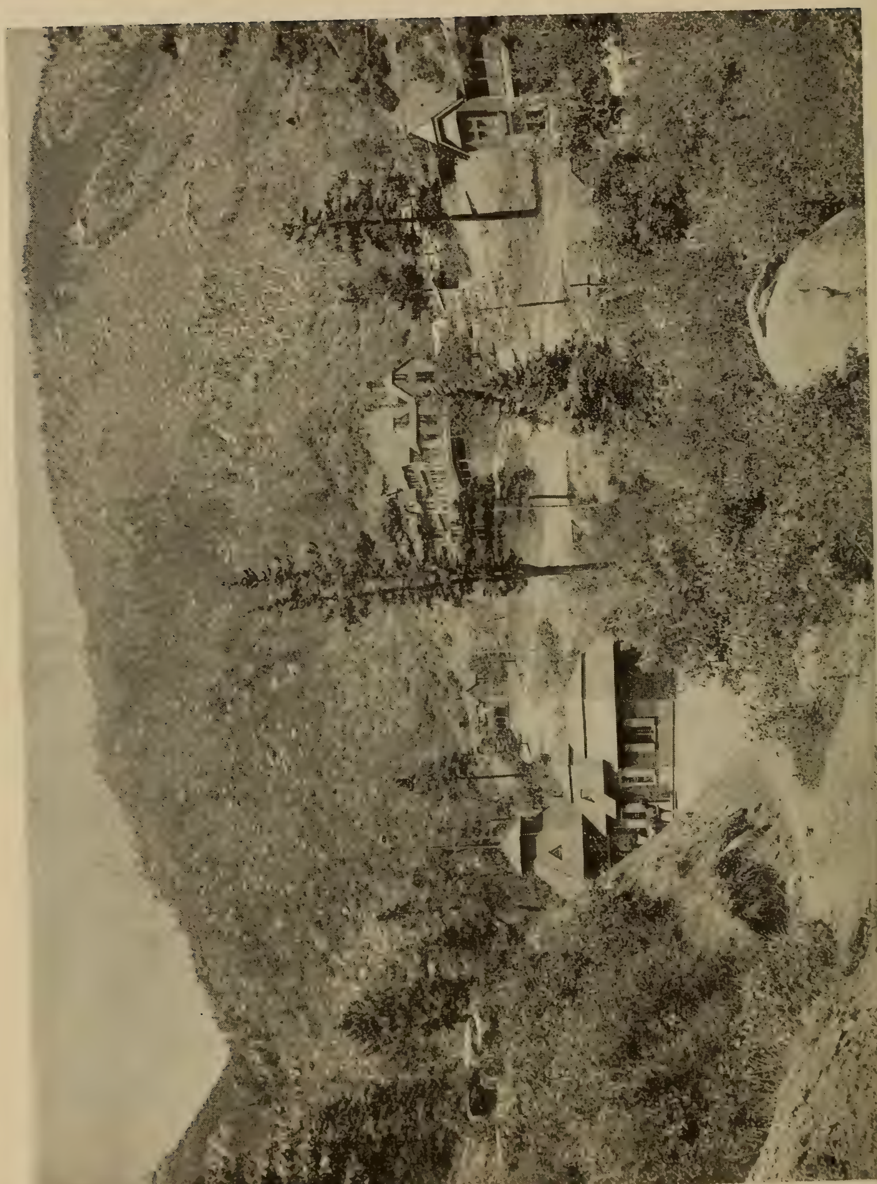


ENGELMAN'S CANON, THE LOWER TERMINAL OF THE PIKE'S PEAK RAILROAD.

To-day, Manitou is an ideal summer resort. A magic transformation has taken place. The Indians have disappeared ; the wild animals have retreated further into the mountains, and where Nature once held sway in rude and savage majesty, art has set up her kingdom. The beauty and grandeur remain ; the springs still bubble up in all their sparkling freshness, and the genius of health still broods over their waters. But the hand of man has polished natural simplicity, and has substituted symmetry and conveniences which make life something more than mere existence. The wonder of it all is, that so many and such great changes should have been made in so short a time. One does not see Manitou from afar. It is so environed by hills that no distant glimpses of it are caught as one approaches by rail. Expectation is thus piqued, and when the beautiful little town is finally discovered as the shoulder of a protecting hill is rounded, it comes as a most pleasant surprise. The town has about two thousand permanent residents, many of them among the wealthiest and most influential citizens of Colorado, and this population is increased, during the season, by from three to four thousand visitors present at one time. There are electric light and water-works, good schools, an excellent sewerage system—everything, in fact, to satisfy modern, advanced requirements, and to help sustain the enviable reputation which the place has made for itself.

Time never hangs heavily on one's hands at Manitou. The thousand-and-one natural attractions of the country guard against that. Not the least striking of these is the Garden of the Gods, which has probably been described and photographed more than any other place of scenic interest in Colorado. The Garden is easily accessible from Manitou, and within its solitude nature has perpetrated many strange freaks of sculpture and of architecture as if she had been diverting herself after the strain of the mighty mood in which the mountains were brought forth. Not inaptly can it be said here that

> "With torrents wild and tempest blast,
> And fierce volcanic fires,
> In secret molds has Nature cast,
> Her monoliths and spires."

Solitude is here unbroken by the residence of man, but inanimate forms of stone supply quaint and groteesqu suggestions of life. Here are found hints of Athens and of the Parthenon, of Palmyra and the Pyramids, of Karnac and her crumbling columns. Many of the monoliths reach heights of three and four hundred feet, two of the loftier ones, with a small space between, making the two portals of the famed gateway of the Garden. Nearly all of them have received appropriate designations. There is a "Statue of Liberty," a "Cathedral Spire," a "Dolphin," a "Lion," a "Griffin," and hundreds of other quaint and curious figures. No words can describe the weird attractions

A GLIMPSE OF MANITOU SPRINGS.

of the place. The impression is of something mighty, unreal and supernatural.

After all, however, the ascent of Pike's Peak has long been the crowning attraction to the visitors at Manitou. When Manitou became a resort of apparent promise, a trail was constructed to the summit of the mountain, and with its completion hardly a day passed during the seasons which did not see a party on horseback making the ascent. Occasionally a hardy mountain climber went up on foot, and in either case the scenery along the trail and the views after the summit was reached were ample compensations for the hardships of the trip. Later, a carriage road was completed, but the ambition roused by these successes looked still further forward, until eventually the rack railroad was built, which now takes one to the topmost pinnacle of the Peak with safety and despatch, leaving one's sight-seeing faculties uninterrupted and free to revel in the gradually unfolding beauties as the higher levels are reached.

CLIMBING THE GRADE. THE OLD WAY.

The first attempt to build a railroad to the summit of the historic mountain dates back only a short time, to the year 1884, when a survey was made to determine whether such a plan was at all practicable. The idea then was to build a road on not very unusual grades, after the manner of other mountain-climbing railroads in the Western part of the United States, without any appliances other than those usually found on ordinary adhesion roads. The report was favorable, and a company was formed to build the line. The course which was put under construction was a series of zigzags for the greater part of the way, with a maximum grade of five per cent. and thirty-degree curves. The road was graded for eight miles and then the project was abandoned, owing, it is said, to the adverse report of an engineer who had been sent out by Eastern capitalists to examine the work. The opinion expressed by him was that washouts would be frequent and unavoidable along the line, and that the expense of

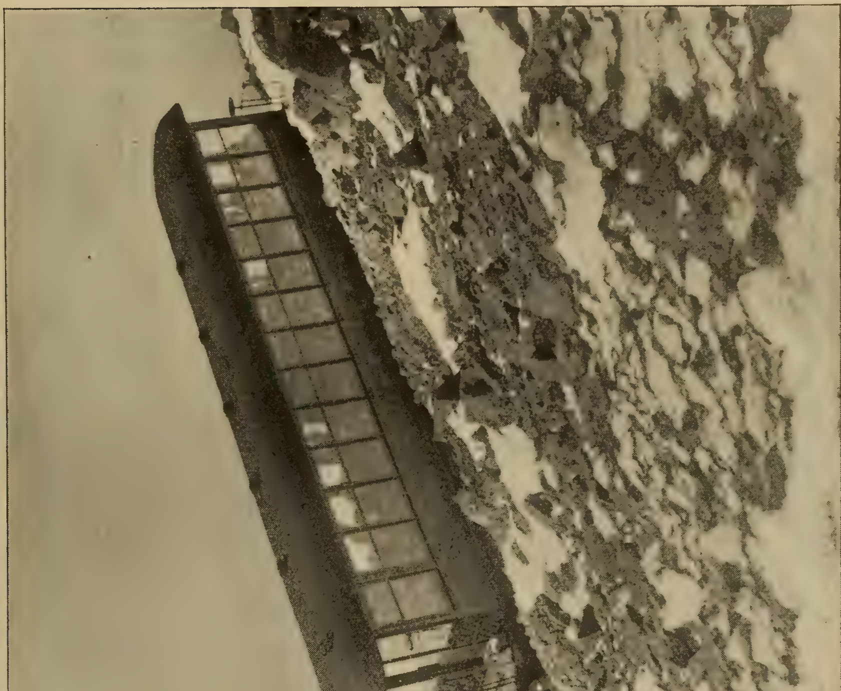
THE NEW WAY.

maintenance would be far too great for profitable operation.

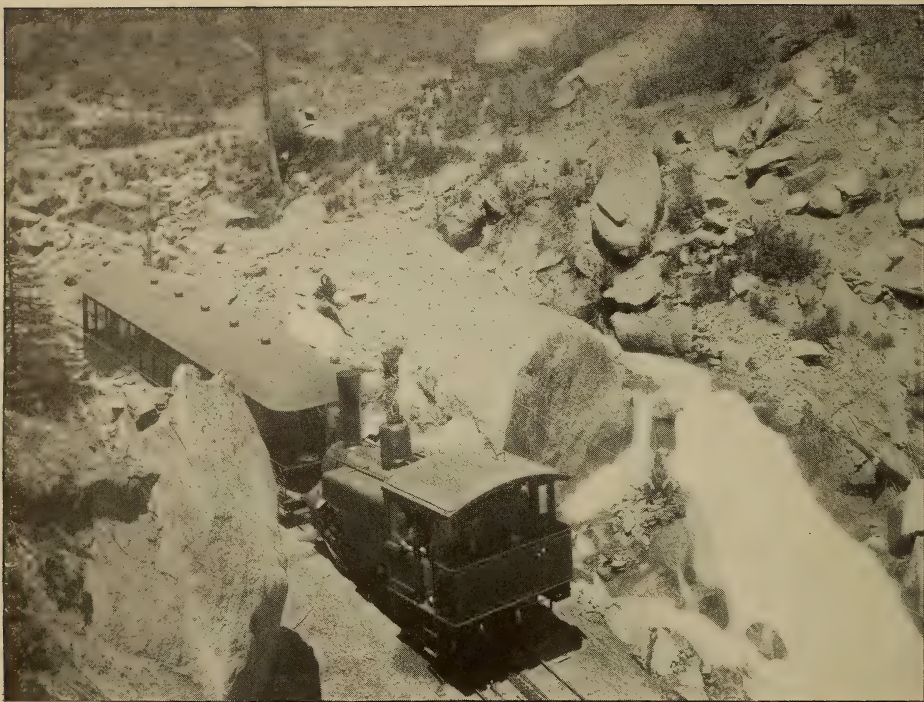
Four years later, in September of 1888, papers were filed incorporating, according to the laws of Colorado, "The Pike's Peak and Manitou Railway Company." The capital stock was $500,000. Major John Hulbert was chosen as president of the company, and it is to his untiring energy that recognition is due for the completion ot the road in so short a time. The sur-

THE PHANTOM CURVE.

A STRAIGHT RUN.



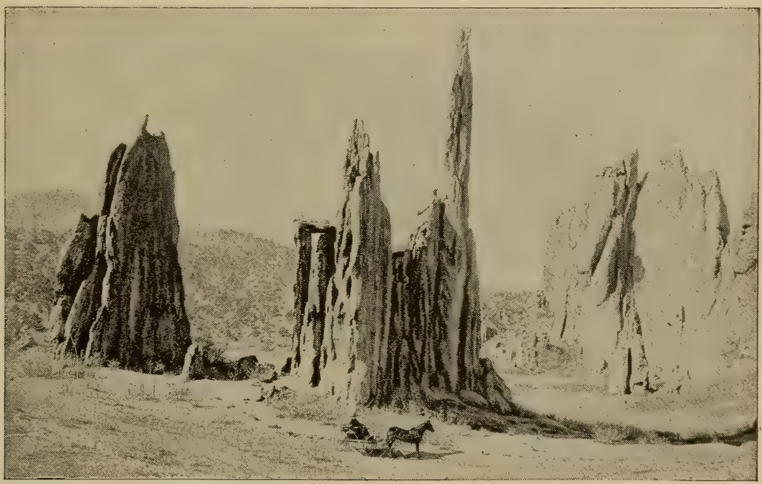
NEAR THE TIMBER LINE.



AT THE ROSE EMMA FALLS.

A BEND IN THE ROAD.

veys for establishing the line were made under great difficulties, and occupied the time of an entire year. They were carried out under the supervision of Mr. D. E. Briggs, Chief Engineer of the Denver & Rio Grande Railroad, and were finally approved by him. What the dangers and labors of making them were can be gathered from the following brief account of one experience :—Mr. T. F. Richardson, chief engineer, and his assistants started for the summit on the first day of April, 1888. The party camped at night their blankets and lay down upon a bed of snow to pass the night. The snow beneath them was five feet deep, and when the morning dawned they found themselves covered a foot deep with a fresh fall of snow. They were only a mile and a half from the camp of the main body of engineers, but it took them ten hours to march that distance against the storm, and over the precipitous and rocky way. They arrived just as a relief party was starting out in search of them. Such experiences were frequent until the warm suns of June



IN THE GARDEN OF THE GODS.

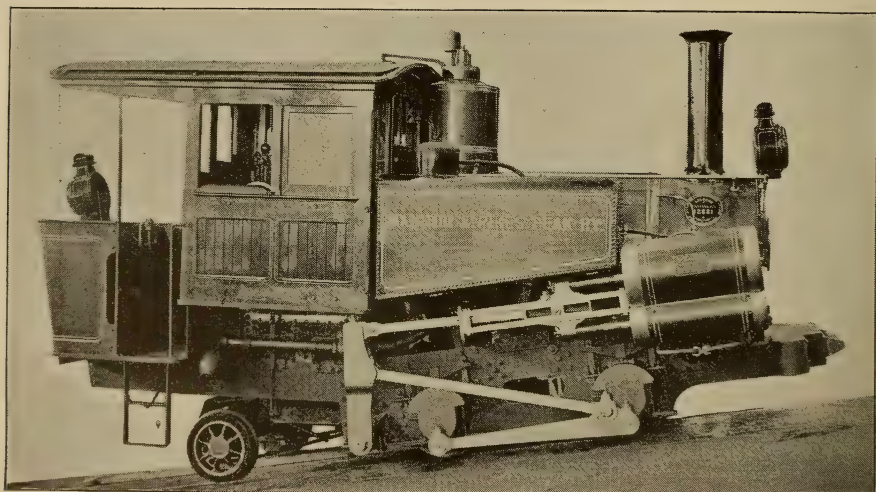
within four miles of the summit, and the engineer started to make a night march with a detachment of his men to reach the top. With wise precaution they took with them four days' rations. No sooner had they reached the abandoned Government signal station on the summit than a most violent snow storm set in. So terrible was the storm, so tremendous the force of the wind, that for four days no one dared venture out from the protecting walls of the stone building in which they were encamped. On the fifth day, being without food, hunger forced them to make a sortie. For twelve hours they battled with the storm, and at last, completely exhausted, they wrapped themselves in melted the snow and made further work comparatively easy.

On September 28, 1889, grading was begun at the summit, and before the winter snows appeared, three miles of the road-bed were completed. During the succeeding summer three more miles were graded, and in the summer of 1891, the whole work was completed and the road given over to traffic. The line is altogether a little less than nine miles long, and when it reaches its upper terminal, above the clouds, at a height of over 14,000 feet above the level of the sea, it renders the famous Mount Washington Railroad in New England almost insignificant by comparison and suffers not from contrast

with even the most noteworthy of the many lines which now scale as many different Alpine peaks in Switzerland.

From its station in Manitou, just above the Iron Springs, to the station on the summit of the Peak, the railroad is, to be more exact, just 8¾ miles long. It is of standard gauge with a wide and substantially built road-bed and heavy steel rails, the traction devolving upon two rack rails in the centre, into which work six cog-wheels underneath the locomotive. The system is essentially that devised by Abt, a German engineer, and much used on the Swiss mountain roads, the peculiar grades. The maximum curvature is only sixteen degrees, which gives a radius of 359 feet. The average ascent per mile is 1320 feet. The total rise from base to summit is 7525 feet. The road is laid with forty-pound steel rails.

The rack rail between these is made up of two parallel steel bars 1¼ inches thick, and placed 1½ inches apart in such a way that the tooth in one plate is opposite the space in the other. The pitch of the teeth is 4¾ inches, and the depth 2 inches. The rack is attached to every alternate sleeper, at distances of 3½ feet, by special rail chairs and heavy bolts. On the already-men-



A MOUNTAIN CLIMBER.

features of both track and locomotive ensuring almost absolute safety. Mr. W. Hildenbrand, the American representative of Mr. Abt, had its execution directly under his supervision. Every two hundred or four hundred feet, according to grade, are sunk cross-sections of masonry, to which the track is tied, so that absolute rigidity is secured. There is not a single foot of trestle-work on the entire line, and only a few stone culverts and four short bridges, these being constructed in the most substantial manner. They are all plate girders resting on masonry abutments. Some of them stand on pretty steep tioned Mount Washington road, as well as on several others, the rack rail is built on the principle of a ladder, giving a cumbersome and noisy construction, and permitting the attainment of but very moderate speed,—scarcely more than about three miles an hour. The speed attainable on the Pike's Peak road is about seventeen miles an hour, but the maximum rate is not over eight miles, and the average not more than four miles. One cog-rail would be amply sufficient to do all the work, but two are inserted to insure safety.

The locomotives were built at the Baldwin Locomotive Works, at Phila-

delphia. When on a level track, they stand at a slant of about eight per cent., so that on the average grade of the line they are about horizontal. The cars, which are pushed up the mountain by the engine, instead of being hauled in the ordinary way, are not tilted, but the seats are arranged so as to bring them about level. On the descent the engine is at the front. Each car has fifty seats, weighs about 21,000 pounds when loaded, and has two pinion brakes worked by hand. The locomotives are tank engines, the tanks being at the sides above the frames. The coal is carried in a bunker at the back of the cab. On each side of the engines there are three wheels which revolve on the axles, and act merely as guides and serve also to sustain the weight. Besides these there are three driving pinions which gear with the rack rails. Each engine weighs about 32 tons. Two cars constitute the usual train, carrying, as a maximum, one hundred passengers, and making a round trip in about three hours, so that a visit to the top of the grand old mountain can be made with ease and comfort in half a day. Ordinarily three trips are made per day. About half-way up the line there is a switch for up and down trains to pass.

Ascending the Peak by rail affords an opportunity of beholding scenery of surpassing grandeur, beauty, and magnitude. The road starts near the Iron Spring, in Engleman's Cañon, and follows this gulch to the head waters of Ruxton Creek. This stream is a typical mountain brook, with cold, clear,

NEARING THE SUMMIT.

sparkling waters, that come dancing down the mountain side, broken into a thousand little cascades and foaming rapids. There are two very pretty falls in Ruxton Creek, called respectively, the Shelter and the Minnehaha. The walls of the cañon are not precipitous, but extend back in long rolling heights

SIGNAL STATION AND DEPOT AT THE TOP OF THE PEAK.

THE CENTER OF PIKE'S PEAK.

on each side of the track, and are clothed with a luxuriant growth of pine and spruce. Along the margin of the creek grow quantities of the mountain ash, whose red berries, flaming through the shadowy twilight of the place, will seem to Eastern visitors like the familiar greetings of an old friend in a strange land. Titanic bowlders, hurled down from granite heights during geologic convulsions in prehistoric ages, lie strewn about on every hand—bowlders of every imaginable form and in every conceivable position. In many places these bowlders are piled in chaotic confusion over the bed of the stream, frequently hiding it entirely from view. About half way up the mountain, and directly on the line of the railway, reached also by the trail, lies the Half Way House.

THE FIRST PASSENGER TRAIN AT THE SUMMIT OF PIKE'S PEAK.

When the head waters of Ruxton Creek are reached, the road curves to the southwest, and "Windy Point" is attained. From here one has a distinct view of Manitou, Colorado City, and Colorado Springs. The "Cathedral Spires," and the "Great Gate-way" of the Garden of the Gods appear like the castles set by the giants for a stupendous game of chess. We are now far above the timber line. On all sides can be seen strange flowers, of lovely form and varied hue. Plants which attain considerable proportions on the plains are here reduced to their lowest terms. It is not an unusual thing to find a sunflower stalk on the prairies rising to a height of from eight to ten feet; here they grow like dandelions in the grass, yet retaining all their characteristics of form and color. Beyond this mountain meadow are great fields of disintegrated granite, broken cubes of pink rock, so vast in extent that they might well be the ruins of all the ancient cities in the world. Far below flash the waters of Lake Morain, and beyond, to the southward, lie the Seven Lakes. Another turn of the track to the northward, and the shining rails stretch almost straight up what appears to be an inaccessible wall of precipitous granite. But no physical obstruction is formidable enough to stop the progress of this marvelous railway; and, passing the yawning abyss of the "Crater," the line proceeds direct to the summit. The grade here is one of twenty-five per cent., and timid passengers will not escape a thrill of fear as they gaze over the brink of this precipice, although there is but little danger. At last the summit is reached, and, disembarking, the tourists can seek refreshments in the hotel, which will cater to their wants, and then spend the time before the train returns in enjoying the view and in rambling over the seventy acres of broken granite which form the summit.

PIKE'S PEAK FROM THE GARDEN OF THE GODS.

THE QUAKERS.

The view from the Peak once beheld can never be forgotten. The first sensation is that of complete isolation. The silence is profound. The clouds are below us, and noiselessly break in foaming billows against the faces of the beetling cliffs. Occasionally the silence is broken by the deep roll of thunder from the depths beneath, as though the voice of the Creator were uttering a stern edict of destruction. The storm rises, the mists envelop us, there is a rush of wind, a rattle of hail, and we seek refuge in the hotel. Pause a moment before entering, and hold up your hands. You can feel the sharp tingle of the electric current as it escapes from your finger-tips. The storm is soon over, and you can see the sunbeams gilding the upper surfaces of the white clouds that sway and swing below you, half-way down the mountain-sides, and completely hide from view the world beneath. The scenery shifts, like a drawn curtain the clouds part, and, as from the heights of another sphere, we look forth upon the majesty of the mountains and the plains. An ocean of inextricably entangled peaks sweeps into view. Forests dark and vast seem like vague shadows on distant mountain-sides. A city is dwarfed into the compass of a single block; water-courses are mere threads of silver laid in graceful curves upon the green velvet mantle of the endless plains. The red granite rocks beneath our feet are starred with tiny flowers, so minute that they are almost microscopic, yet tinted with the most delicate and tender colors. The majesty of greatness and the mystery of minuteness are here brought face to face. It is in vain that one strives to describe the scene. Only those who have beheld it can realize its grandeur and magnificence.

It is fitting here that credit be given for much of what has appeared in the foregoing pages to the several publications of the Denver & Rio Grande Railroad Company, many miles of whose lines extend through the most picturesque and striking of the Western mountain regions. The tourist books of the company have detailed the beauties of that country at length, and not a little of their substance has been devoted to the venerable mountain treated of here, and to the railroad leading to its summit.

RAILWAY FREIGHT RATES.

By Harry Turner Newcomb.

IN every enterprise undertaken for commercial gain, the price of transportation is an important factor. This is particularly true in the United States where the diversity of natural resources and the great distances separating the dense centers of population in the East from the sources of their food-supply in the West, combined with the modern tendency toward localization of particular branches of industry, render cheap transportation an essential of prosperity.

In supplying this necessity and in its lower cost, compared with any other means available between localities not connected by natural waterways, railway transportation has its chief value to the public. Whoever, therefore, would determine the extent of the contribution to progress made in the development of the railway system will find a not inadequate measure in comparative study of the cost of transportation by that and other means, and an increasing public utility will appear if it is found that its charges have constantly declined. Frequent mention has been made of the existence of a constant tendency toward lower charges for freight tranportation by rail, yet it is believed that few are aware of the extent of the reductions which have been effected.

One method of showing changes in rates that affords at once a comprehensive view of the entire subject, is by a comparison of average charges per ton per mile during different periods. It has the manifest advantage that it includes all traffic and presents the actual net result of all changes, whether advances or reductions. As there is a natural decrease in the average rate per ton per mile as the distance carried increases, some portion of the apparent reductions on such a statement is, doubtless, due to the increase in the average distance hauled. In order that the importance of the reductions given in the statement on the next page, which shows the average rate per ton per mile charged by several important railways during successive years, may be fully appreciated, the number of millions of tons of freight carried one mile is inserted wherever practicable. In preparing this statement an effort was made to select railways fairly representative of the sections in which they are located.

Probably a greater number of the people of the United States are affected by the rates charged between the cities of New York and Chicago than by those between any other cities that could be named. Their commercial importance and location, one at the gateway of commerce entering from the Old World, the other at the portal of the Great West, seem to sufficiently attest this fact, which becomes irresistibly evident when it is understood that rates between cities are the basis of rates upon nearly all traffic in the territory north of the Potomac and Ohio and east of the Mississippi rivers, and that any change in them immediately effects a corresponding alteration in those from or to nearly every station in the territory described. The yearly average rates from New York to Chicago upon a few articles of general consumption, all of which move from the East to the West, are given below:

YEAR.	Rates in Cents Per 100 Pounds. Cotton Piece Goods.	Stoves in Carloads.	Coffee in Carloads.	Starch in Carloads.	Sugar in Carloads.	Common Soap in Carloads.
1867	190	190	162	162	83	129
1880	75	40	40	40	40	40
1893	50	25	25	25	25	26

AVERAGE RATES PER TON PER MILE AND NUMBER OF MILLIONS OF TONS CARRIED ONE MILE.

NAME OF RAILWAY.	YEAR. 1852.		1857.		1862.		1867.		1872.		1877.		1882.		1887.		1889		1891.		1892.	
	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.	Ton—Mile Rate.	Millions of Ton—Miles.
	cts.		cts.		cts.		cts.		cts.		cts		cts.		cts.		cts.		cts.		cts.	
Fitchburg R. R	3.12	----	3.93	----	3.75	9	4.21	14	3.92	20	2 08	53	1.17	129	1.13	239	1.02	346	0.99	437	0.93	496
New York, New Haven and Hartford	----	----	4.44	----	4.50	3	4 94	7	3.74	39	3.34	40	1.76	117	1.95	150	1.83	225	1.79	255	1.76	280
New York Central and Hudson River	----	----	3.12	166	2.22	358	2.46	435	1 59	1,021	1.01	1,620	0.73	2,395	0.78	2,705	0.71	2 781	0.74	2,890	0.70	3,830
New York, Lake Erie and Western	1 95	97	2.46	165	1.89	351	2.04	550	1.53	951	0.96	1,115	0.75	1,954	0.69	3,022	0.64	3,109	0.66	3,496	0.61	4,048
Pennsylvania R. R	5.42	----	2.41	140	2.04	376	2.08	566	1.46	1,190	1.01	2,180	0.87	3,977	0.73	5,261	0.69	5,834	0.66	6,870	0.65	7,362
Lake Shore and Michigan Southern	----	----	2.74	----	2.10	----	2.43	----	1.37	925	0.86	1,080	0.63	1,893	0.67	1,844	0 63	1,782	0.63	2,061	0.60	2,430
Michigan Central	----	----	----	----	1.91	82	2.49	92	1.56	217	0.98	474	0.77	703	0.69	1,341	0.70	1,214	0.72	1,298	0.69	1,548
Pittsburgh, Ft. Wayne and Chicago	----	----	2.27	29	1.90	126	1.95	229	1.40	488	1.09	440	0.75	992	0.72	1,107	0.69	1,087	0.70	1,122	0.67	1,300
Chicago, Milwaukee and St. Paul	----	----	----	----	----	----	3.94	96	2.43	187	2.08	272	1.48	945	1.09	1,629	1.07	1,621	1.00	1,896	1.03	2,266
Chicago, Rock Island and Pacific	----	----	----	----	----	----	3.05	80	2.49	169	1.71	337	1.28	788	1.01	794	0.97	903	1.04	1,082	1.06	1,188
Union Pacific	----	----	----	----	----	----	----	----	2.34	178	1.92	335	2.21	733	1.42	1,490	1.17	1,102	1.13	1,209	1.08	1,318
Ohio and Mississippi	----	----	----	----	2.35	----	----	----	1 71	108	1.04	x	1.17	179	0.72	334	0.81	273	0.94	249	0.91	271
Illinois Central	----	----	----	----	1.96	----	2.90	171	2.16	272	1.82	249	1.42	418	1 09	831	0 84	1,061	0.93	1,302	0.91	1,411
Mobile and Ohio	----	----	----	----	----	----	----	----	3.77	57	2.63	61	2.15	75	1.32	133	0.96	218	0.87	306	0.85	302
Louisville and Nashville	----	----	----	----	----	----	4.13	----	2.30	----	1.76	202	1.35	597	1.02	954	1.00	773	0.97	902	0.95	1,051
Chesapeake and Ohio	----	----	----	----	7.57	----	5.22	5	4.08	9	1 10	117	0.79	345	0.54	653	0 54	612	0.53	1,136	0.52	1,292
Richmond and Danville	----	----	----	----	----	----	----	6	4.96	10	2.92	22	1.95	119	1.92	x	1.48	428	1.42	473	1.36	468
All railways in United States	----	----	----	----	----	----	----	----	----	----	----	----	1.24	39,302	1.03	61,561	0.92	68,727	0.90	81,074	0.90	83,241

If the foregoing statement could be extended to include all of the more than 5000 commodities enumerated in the official classification used by the railways, it would show similar reductions upon nearly every article of interstate commerce. North of the Ohio and Potomac rivers by far the greater portion of eastbound traffic, exclusive of that strictly local to individual lines, consists of food products; chiefly grain, grain products, including flour, live stock and dressed meats. The tonnage of these articles shipped from Chicago during 1892, via seven of the ten railways having lines eastward, was as follows:

Commodity.	Tons.	Per Cent.
Flour	221,884	5.24
Grain	1,166,182	27.53
Salt Meats	241,601	5.70
Lard	120,673	2.85
Live stock and dressed meats	1,532,450	36.18
Total, food products	3,282,750	77.50
All other traffic	952,885	22.50
Grand total	4,235,635	100.00

The live stock and dressed meats carried by the three roads omitted from the foregoing amounted to 184,660 tons. No record is available showing their tonnage of the other commodities named, but the proportion is not likely to have varied greatly from that for the other lines. The great saving effected by the reductions which follow will be evident if the quantities shipped are borne in mind.

The rates per 100 pounds on grain from Chicago to New York during the year 1864, the earliest for which data are available, ranged from 75 cents, in effect, for about three months during the season of navigation when the competition of boats upon the great lakes was felt, to $1.60, which was put in effect soon after its close and continued until April 22, of the following year. During the years immediately following, considerable decline took place, the highest and lowest rates of 1870 being 60 and 45 cents respectively. In 1880 the highest rate was 40, the lowest 30 cents, and during 1890 the present rate of 25 cents prevailed nearly the entire season. This rate was in force throughout 1893 until December, during which it declined rapidly to 15 cents, only to be restored to the former figure on January 1, 1894. It should be remembered that these rates are not only those at which grain is carried from Chicago to New York, but the basis of all rates on grain from the West to the East, consequently governing the charges for transporting nearly every bushel raised in the United States and not consumed at or near the point of production. Flour rates have generally been the same as those on grain. Similar reductions in the rates charged on live stock and dressed meats from Chicago to New York are shown below:

Date.	Rates in Cents per 100 Pounds.				
	Cattle.	Hogs.	Sheep.	Dress'd Beef.	Dress'd Hogs.
1880, Jan. 1.	55	55	65	88	xx
1885, Jan. 1.	40	30	50	70	xx
1890, Jan. 1.	26	30	30	45	45
1894, Jan. 1.	28	30	30	45	45

As a reduction of only five cents per 100 pounds on the tonnage of live stock and dressed meats shown for 1892 would amount to $1,717,110, the importance of these reductions is apparent.

A saving of considerable importance to the public has been effected by changes in the rates on anthracite coal. Taking, as an example, the rates of the Lehigh Valley railroad from collieries located in the Wyoming region of Pennsylvania to Buffalo, the earliest data available show that on August 1, 1875, the rate was $4.09 per gross ton; five years later it was $2.87; in 1885, $2,35, and on January 1, 1894, $2.25. On bituminous coal from the Clearfield region, Pennsylvania, the average rate per gross ton, during 1873, was $4.05, had declined to $3.33 in 1883, and in 1893 was $2. The present rate on cotton, in bales, from Memphis, Tenn., by rail to New York city, is 50½ cents per 100 pounds, having declined from 74 cents on September 1, 1880, the earliest date for which data can be procured. Similar instances of reductions could be multiplied indefinitely, but sufficient have been given to

establish the existence of a tendency toward lower rates and to illustrate its extent while suggesting an inquiry regarding the causes which have produced it. Primarily, it may be said that legislation prescribing maximum rates is not among those causes, and this need not provoke discussion concerning the wisdom of such legislation, for it is merely intended to insist upon the total inadequacy of this cause to the effect. Legislation of this kind has been limited to a few States, nearly all west of the Mississippi river, while reductions have covered the whole country, and have been most noticeable where there has been least legislation. Commercial and industrial conditions inseparably connected with the development of the country, assisted by an enlightened consciousness upon the part of railway officials that the only certain road to the financial prosperity of the properties under their charge lay in building up the territory contiguous to their lines, which could not be accomplished with rates unreasonably high, may be assigned as the chief causes of the decline. The shipping public are constantly appealing for lower rates. The manufacturer sees in a reduction of a few cents, or even a fraction of a cent per 100 pounds, an opportunity to put the commodity which he produces into more distant markets, or to underbid his competitors in those already reached. Should he obtain the concession sought, it must now be made as a rate open to all shippers of similar goods in his immediate locality, and it might be supposed that no other interests would be affected. So delicate, however, is the adjustment of the industrial organism that such a change may affect competing manufacturers in far distant localities who, thus placed at a disadvantage in the common market, at once seek corresponding reductions, which the railways must grant or lose a portion of their traffic.

A large traffic at low rates will frequently produce greater net revenue than a small traffic at high rates, and the single aim properly before every railway official having control of rates is at all times to make these rates which will move the greatest quantity of traffic without increasing the cost of operation faster than the gross earnings. Competition between carriers is often assigned as the principal cause of declining rates, but experience shows that few, if any, of the low rates forced by competition become permanent. Fierce rivalry for traffic sometimes results in extremely low rates, which, often secret, and consequently discriminating against particular shippers, are invariably limited in their application to the competitive points, and therefore place others at a disadvantage. After a period of such rates, depleted revenue usually causes an agreement to maintain rates, which are restored to figures as high or higher than those previously in vogue.

From certain sections of the country the cry is constantly arising that railway rates are extortionately high. Considerable light is thrown upon the sufficiency of the evidence offered to support this charge by a statement made in the seventh annual report of the Interstate Commerce Commission that during 1892 no interest was paid upon railway bonds having the par value of $777,719,420, or 15.56 per cent. of the aggregate, nor any dividends upon $2,807,403,326 of par value of stocks, or 60.60 per cent. of the entire share capital. The freight service performed by the railways of this country during 1892 was equivalent to moving 88,241,050,225 tons one mile; the compensation therefor was $799,316,042, and the average rate, 0.898 cent per ton per mile. A reduction of only one mill in this average would have amounted to nearly 90 per cent. of all dividends paid during that year, and as the average rate of dividend was only 2.11 per cent., it is doubtful if anyone will contend that it should be reduced to that extent. Particular rates may be, and doubtless are, in a few instances, unreasonably high, but the fact that the general income account of all railways west of the Mississippi and Missouri and south of the Ohio rivers shows a deficit, is evidence that if they exist in those localities they are compensated for by

others unreasonably low. The necessity for cheap transportation stops at the point where equal justice is accorded both shippers and railways, and it is not desirable from any point of view that the business of transportation should be unprofitable. To require railways to carry traffic at a loss is to determine in favor of poor service, instead of good, of bankruptcy rather than solvency, and of commercial depression rather than prosperity; for service cannot continue good unless earnings will replace and repair worn equipment and road-bed; interest upon bonds will not be paid unless earned; nor will the country continue prosperous while one important interest is being destroyed.

Are there to be further reductions, or has the price of freight transportation by rail reached its minimum? Under existing conditions it is improbable that reductions as extensive as those cited will take place, though gradually the growth of population in localities now sparsely settled will increase traffic and permit greater economy in operation which will accrue to the benefit of shippers. If, however, reductions equal to those of the past are to occur, most radical economies must be effected. These, unless arrested by adverse and ill-judged legislation, will be permitted by the consolidation of connecting and competing lines, either actually into single corporations, which is to be preferred, or, what approximates that result, by agreements for pooling competitive traffic. Either of these, if broad enough in scope to be effective, would abolish such wasteful competition as that which, among other extravagances, is responsible for the existence at the present time of more than 100 routes actively competing for traffic from New York to New Orleans, many of them being 50 per cent. longer than the shortest. Actual consolidation would afford still further economy by discontinuing expensive separate organizations with their duplication of official machinery. It is devoutly hoped that wise and enlightened public sentiment will so guide future legislation that no obstacle will be placed in the path toward cheapening transportation which has been aptly said to be as essential to the industrial, as the atmosphere is to the physical, world.

A VIEW OF THE COLLEGE BUILDINGS.

TECHNICAL SCHOOLS OF AMERICA.—V.

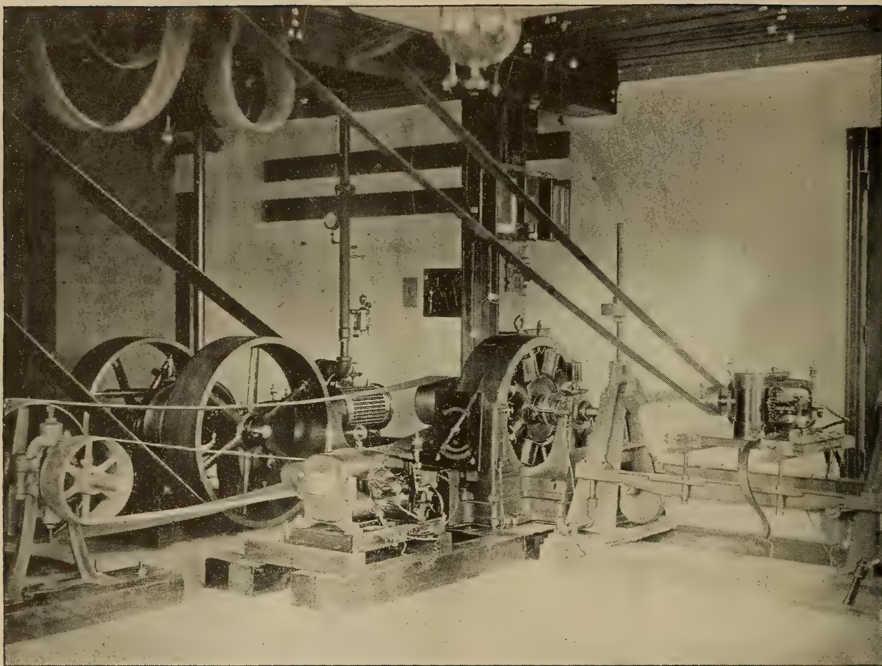
THE PENNSYLVANIA STATE COLLEGE.

By Edwin J. Haley, A. M.

MAIN ENTRANCE TO ENGINEERING BUILDING.

THE Pennsylvania State College is, as its name implies, a State and not a denominational institution. It is situated in the small village of State College in one of the most picturesque and healthful localities of central Pennsylvania. Practically surrounded by mountains, with Nittany on the east, Tussey on the south, and Muncy on the north, it is, as the poet says of Lake Constance, "girt round with rugged mountains," yet the rugged mountainous view is relieved by the more restful and peaceful beauty of the foot-hills and lowlands, forming a well contrasted panorama of natural scenery. The college campus of sixty acres, containing the numerous college buildings and professors' residences, is artistically laid out with drives, avenues and walks, with here and there a secluded bower or romantic work, and well merits the title of the ideal college campus so often bestowed.

The College is one of the so-called land grant colleges, established under the act of Congress of July, 1862. The section of the act relating directly to the character of the work to be pursued by the institution reads: "The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and mechanic arts in such a manner as the legislature of the State may prescribe, in order to promote the liberal and practical education of the industrial class in the several pursuits and professions of life." The State Legislature accepted this act of Con-



IN THE DYNAMO-ELECTRIC LABORATORY.

gress, and further "pledged the faith of the State to carry it into effect."

It is interesting, in the history and development of technical institutions in America, to note the early assistance which the National and State Governments rendered the branch of modern education which they represent. It is highly laudable in the exponents of the Morrill act that they should have had the foresight, and been sufficiently in touch with the growing needs of the day, to establish the means for the higher education of the youth of the land in those branches that bear directly upon the practical and technical subjects. The unprecedented development of technical education, has been but the result of the demands of the times. We are living in a practical age, an age in which, as General Francis A. Walker says, "The scions of our best families are no longer ashamed to be seen winding an armature, or charging a furnace, or working at a lathe in a paper cap, a leather apron, and hobnailed shoes." The influence of a technical institution is definite, immediate and tangible. From the moment a student enters a technical college, he has a definite end in view, *i. e.*, to become a specialist in one of its departments. The so-called land grant colleges have registered each successive year an expansive growth along the line of practical work, until now fully two-thirds their number have outgrown their original titles, and have clothed themselves with the broader name of university; the remaining ones are more than prepared to take this step in advance. The president of one of America's greatest scientific schools, in speaking of colleges of the nature of the Pennsylvania State College, has said: "How well this class of institutions have, from a purely practical point of view, justified their creation in the contribution they have made in the development of the national resources and in the direction given to national industry, it is not needful to say."

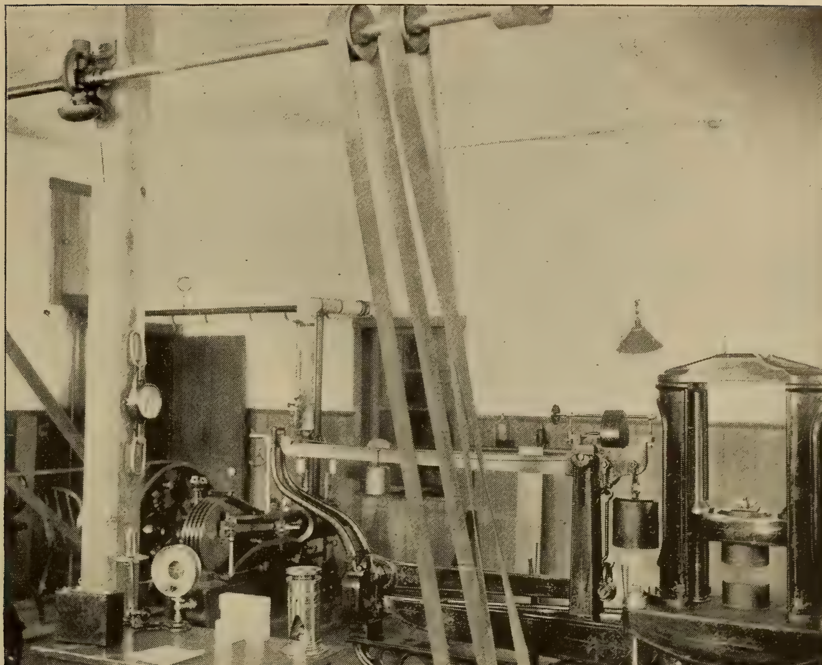
The Pennsylvania State College claims to have accomplished as much as

any of the land-grant colleges toward the true purpose of its class,—that of imparting a liberal, practical education in the line of industrial work. The rapid growth of the institution into a position of national prominence has taken place within the last decade and has been the result of the policy adopted by the present executive, Dr. George W. Atherton. Previous to his inauguration the college had gained scarcely a local reputation, and was on the verge of a retrograde movement. He immediately outlined the present courses of technical work, and the degree of success which they have attained is sufficient evidence of their practicability and the demands of the times for instruction of such character. As an additional testimonial of the appreciation and recognition of the facilities offered in the various technical departments it is noteworthy that only four years ago less than ten per cent. of the student body were pursuing technical instruction, while to-day over ninety per cent. are classified in the departments devoted to it. The college has always sought to combine practical with theoretical instruction, and thus to establish firmly in the student's mind a knowledge of both methods and principles. The greater part of the training is technical, and consequently almost entirely confined to certain courses. Other "practicums," as they are called, are so general in their character as to be appropriately required of all students. Among those "practicums" common to all may be mentioned free hand and mechanical drawing, military drill required by law, mechanic arts, in which are learned the care and use of tools and the principal processes which lie at the foundation of all mechanical industries without leading to any specific trade, surveying and chemistry. Some of these "practicums" not only give knowledge of almost universal use but also serve to develop, during the early part of the course, tastes and aptitudes which may decide the student's choice of a technical course and of his life work.

REAR VIEW OF THE ENGINEERING BUILDING.

THE ELECTRICAL ENGINEERING AND CHEMISTRY BUILDING.

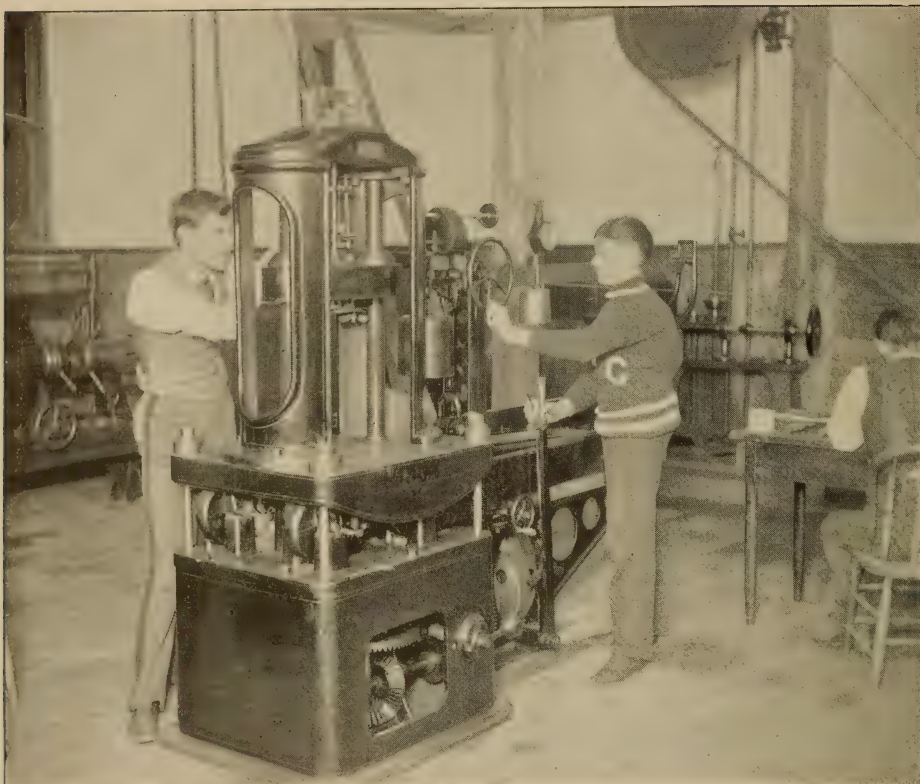
A ROW OF PROFESSORS' RESIDENCES.



TESTING ROOM IN THE MECHANICAL LABORATORY DEPARTMENT.

It may be thought that the variety of operations in the mechanic arts, for example, is so great as to make it impossible to give the student any valuable information in the time at his disposal; it should be borne in mind, however, that this multiplicity of processes may be reduced to a small number of manual operations, and that the numerous tools employed are only modifications of, or convenient substitutes for, a few tools which are in general use. The uses of the lathe are, to a great extent, the same whether the material is bone, metal or wood. Again, as fitting depends on a correct eye and manual skill, the training process is essentially the same whatever the materials employed. The practicum in mechanic arts is required of all students at some stage of their course, but those who wish to devote themselves exclusively to this branch of work generally enter the regular course of mechanical engineering. It is the object of the present article to treat only of the technical courses in operation at the college in question, with simply a passing reference to the other departments.

There is probably no department of college work that has elicited more favorable comment and recommendation within the last few years than that of mechanical engineering. In the early history of technical institutions the need for special engineering courses was not recognized. A single department, including all the widely divergent engineering professions, was the sole means which the most advanced colleges offered. With the completion of his collegiate work the student received the degree of engineer, with no specification as to whether civil, mechanical, mining or electrical. But the age of specialists soon demanded the engineer to be proficient in one branch of the science and forthwith there were established, crudely at first, those departments that annually turn out young men who, in addition to having a general knowledge of the



TESTING MACHINE IN THE MECHANICAL ARTS DEPARTMENT.

whole science of engineering, are specialists in one of its many branches. At the Pennsylvania State College the mechanical engineering department has steadily developed, so that at length it has outgrown its first allotted space in the main college building, and, in conjunction with the other departments of engineering, is now located in extensive and commodious quarters in the new engineering building which occupies a prominent site near the upper front entrance to the campus. On the one side it faces the main entrance and the roadway, and on the other the main street of the village. It is built of red pressed brick with brown stone trimmings. The most striking feature of the front is the great stone arched entrance, supported on short cylindrical columns on either side, and extended above into a projection from the rooms of the different floors. The building is three stories high with a basement under the whole, and has in the rear a wing of one story and attic. It faces the roadway a total length of 266 feet, and extends 208 feet to the rear, covering a total area of a little more than an acre. The interior floor surface covers two and one-third acres, and contains fifty-seven rooms. The new building adds another variety of material and style to the nineteen buildings already on the campus. The 22d of February, 1893, the day of its formal opening and dedication, marked the beginning of a new era in the history of the college. Appropriate dedicatory exercises were held in the college chapel, and addresses delivered by Hon. John W. Noble, ex-Secretary of the Interior; Hon. Edwin Willets, ex-Assistant Secretary of Agriculture; Gen. Francis A. Walker, President of the

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Massachusetts Institute of Technology; Hon. Robert E. Pattison, Governor of Pennsylvania; ex-Governor James A. Beaver and President George W. Atherton.

The practical work in mechanical engineering begins in the freshman year with a systematic course of shop work, including carpentry, wood-turning, pattern making, molding, foundry work, forging, vise work and machine-tool work. The student thus gains facility in the handling of the tools and materials which enter into the construction of machines, and becomes acquainted with methods of shop work early in his career. After the elementary work in the shop has been completed, each class is required to build a complete machine, as far as practicable, from their own drawings.

In order to be fully prepared for the more technical studies of the mechanics of machinery and "Applied Mechanics," a carefully selected course in the rudimentary principles of mechanics is given during a part of the sophomore year. The student is made familiar with machines of various forms, and pursues a systematic study of motion in relation to these various machines, of how it is constructed, distributed and conveyed. The formulæ relative to force and motion herein developed are directly applied to machines in the shops. In the study of graphical statics of machinery, the efficiency of machines is determined by graphical methods. This embodies methods of observing sliding, journal, chain, gear-wheel and other kinds of friction, and how it is modified and affected by the size and form of the parts. The efficiency of a number of machines in the machine shop is calculated by the students by this method and is compared with results of actual tests. In the study of descriptive geometry, theory and practice are united, giving the students a thorough training in graphical expression of ideas and principles.

A course in applied mechanics is offered during the junior year, including statics, kinematics, kinetics and dynamics of solids and fluids. During the same year a theoretical and practical study of valve gearing and link motion is taken up. The mathematical equations involved are applied to sectional working models of various types, a method which at the same time helps to elucidate the abstract formula and gives to it a practical value. A thorough investigation of the various kinds of valves and link motions occurring in different types of machines, engines, and pumps is part of the work done under this head. A prominent place in the curriculum of the junior year is given to work upon materials of engineering. Special attention is devoted to the manufacture and composition of iron and steel, not omitting, however, due consideration of the other metals. The relative strength of materials is dealt with, as well as their strength and durability as affected by conditions to which they may be subjected. In the text-book work upon boilers, in addition to a study of the general construction as to strength and form, particular

THE ARMORY AND GYMNASIUM.

ONE OF THE MECHANICAL ENGINEERING DRAWING ROOMS.

attention is paid to the rules adopted by leading manufacturers as to grate area, heating surface, etc. Combustion and evaporation tests, including flue gas analysis, are carried on in connection with this work. The college boilers, which furnish heat and power for the buildings upon the campus, are especially arranged for this purpose.

The work of the mechanical engineering student in physics is mapped out with special reference to heat and electricity—the study of heat as preparatory to the subsequent work in thermodynamics, and electricity leading to the study of dynamos and the electrical transmission of energy in general.

The work of the senior year embraces a rigid course in the theory of thermodynamics, supplemented by tests made on the steam engines in the shops. Knowing theoretically what results should be obtained in pounds of steam per horse-power under perfect conditions the student in practical work can observe the actual results under working conditions and thus gain a better appreciation of the actual losses which must necessarily occur in the operations of the steam engine. Indicator practice is also carried on at the same time, and valuable experience is acquired by taking and interpreting indicator cards. The load upon the engine is varied and measured by means of the various absorption brakes in common use. Complete steam engine tests are made under conditions approximating closely to those of actual practice, for this special branch of the work. A course of sixteen lectures on lubricants is given, and careful tests of oils and other lubricating agents are made upon oil testing machines. In the study of steam heating and ventilation an excellent opportunity for experimentation and observation is afforded by the large steam plant furnishing heat to all the

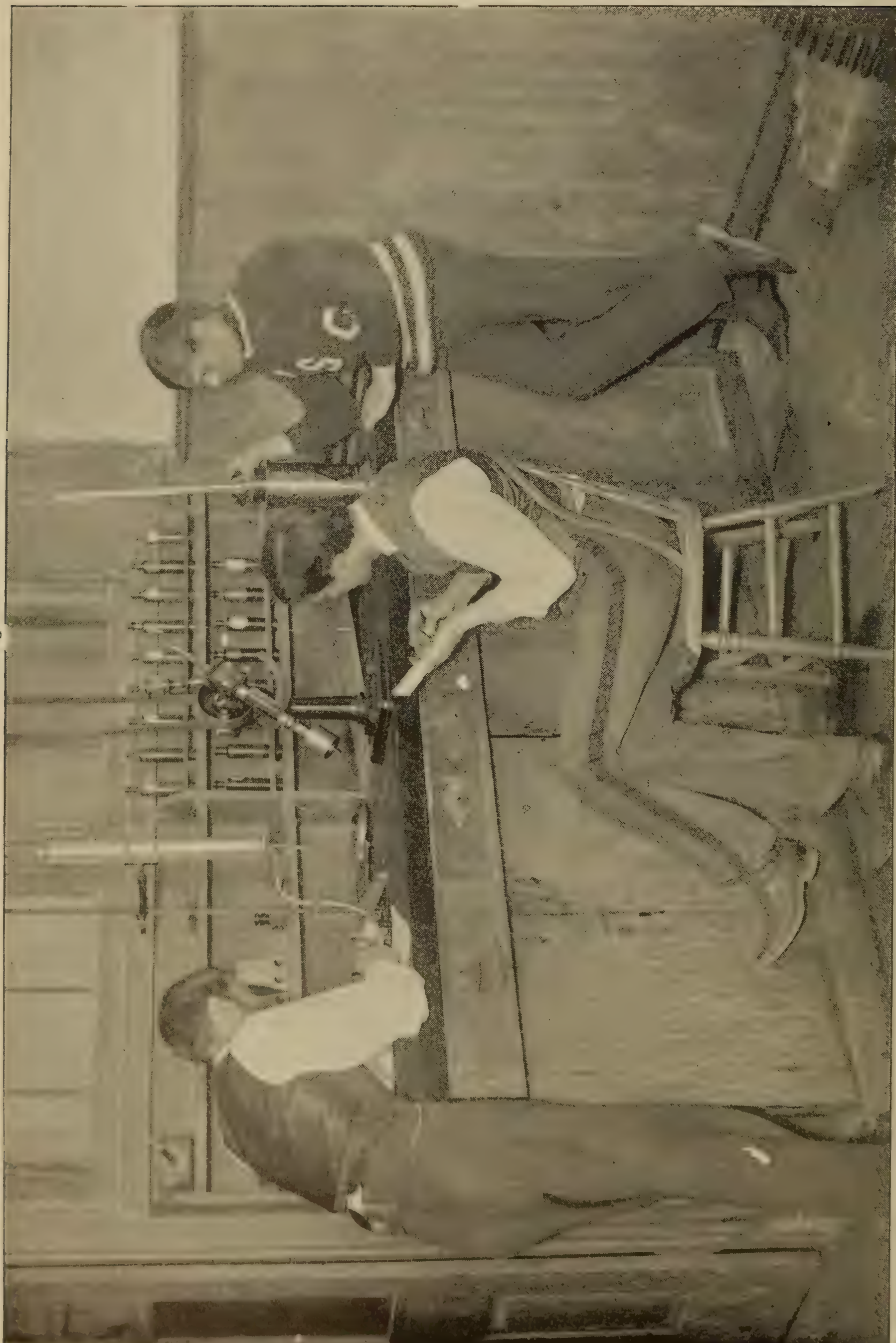
college buildings, different methods of heating and ventilating being employed in the different buildings.

The entire third floor is devoted to drawing rooms, beautifully lighted, with small adjoining rooms for making blue prints, photography, storing of materials and finished work.

PRESIDENT GEO. W. ATHERTON, LL.D.

The course of instruction in machine design extends practically through the entire four years, the student working with application of definite formulæ until he has reached such a point of advancement in his mathematics as to enable him to deduce formulæ and originate designs. Each student is required to design parts of large mechanism or complete small machines, with a view of constructing them in his shop-work course. For the junior and senior years this branch of the work embraces machinery of transmission, hoisting and pumping machinery, ventilating and transporting machinery, the steam engine, and mining machinery. Hydraulic motors and their principles also are studied by experiments upon turbines and other water wheels in use. In addition to the subjects bearing closely upon the science of mechanical engineering, a comprehensive knowledge of political science is acquired during the last year, as it is believed that the training and benefit gained from this subject not only broadens the engineer's general education, but may be of direct use to him professionally. One modern language, besides English, is also required in order to facilitate advanced research in the literature of mechanical engineering. Excursions are frequently made to engineering establishments with the view of affording opportunity for the direct study of current practice. For instruction

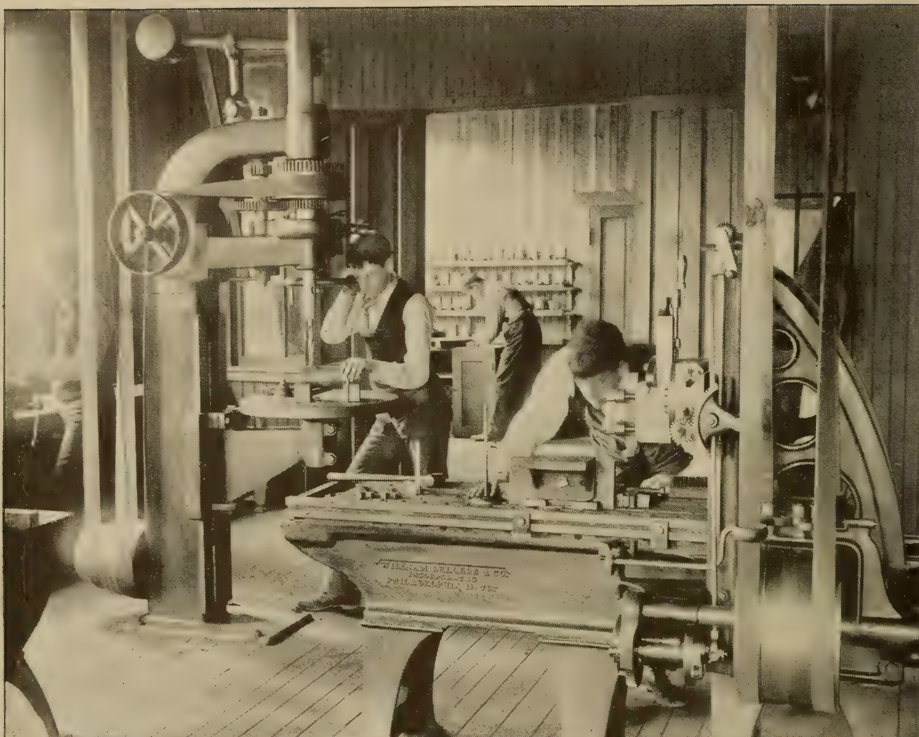
A CORNER IN THE ELECTRICAL SHOP.



IN THE OIL-TESTING ROOM.

in carpentry during the first year, a carpenter shop is provided in which there are thirty specially designed benches, each fitted with two vises, two drawers, and two closets, arranged with racks for holding the tools to be used. After each piece is finished, it is marked and put in a case provided for that purpose. From the carpenter shop the student goes into the wood-turning room. Here are twenty-five wood lathes, each provided with the proper tools. The pattern room, next in order, has, in addition to its dozen benches, fitted up with pattern maker's tools, a scroll saw, a band saw, a cross-cut and rip saw, a pattern maker's lathe of special design, and a universal wood worker. The room directly above this is fitted up with a large rip and cross-cut saw, and a twenty-two inch wood planer. The forge has twenty-five forges of the Sturtevant make, a fan being used to furnish blast. Another fan is used for drawing off the smoke. There is here also an emery wheel, an iron shears, and all the small tools required in the work to be done. The iron and coal to be used are conveniently stored in two small rooms adjoining. The machine shop, directly across the hall from the forge, has benches along two of its sides, provided with twenty vises. With each vise there are two drawers in which the student's work is kept, and a full set of tools for chipping and filing. Here there are, also, a variety of machine tools. Among the engine lathes are Pratt & Whitney's, Reed's, Gould & Eberhard's, Harrington's and others. There are, also, a shaper, a Sellers' drill press, a Browne & Sharpe milling machine and several hand lathes. The foundry equipment consists of a Colliau cupola, with all the necessary appliances for its use, and of a small brass furnace. The pipe-cutting and fitting-room, pro-

THE BLACKSMITH SHOP.



A GLIMPSE AT THE MACHINE SHOP.

vided with a large pipe threading machine, is used to some extent by students. The shafting in the shops is reduced to a minimum by having an electric motor in each room and one on each fan, so that the power in each room is entirely independent of that in any other room. The entire basement of the engineering building is devoted to laboratory work, and is well equipped.

For testing materials, a Rhielè 100,-000-pound tensile machine, a Rhielè torsion machine, and a Thurston autographic machine are in use. A 200,-000-pound tensile machine will be added this year. The equipment for lubricant testing includes Thurston's machine for friction tests and various appliances for the determination of the flashing point, viscosity, acidity. For experimental work in steam there is an Ide engine fitted up with a Prony brake of special designs, a Wheeler surface condenser, and Blake pumps. The foundations are in for a triple-expansion engine of 150 horse-power. This engine is now being built by the E. P. Allis Company, of Milwauke. It is specially designed for experimental work, and will have a variety of brake attachments. It will be so adjusted as to exhaust into a surface condenser, a jet condenser, or into the air, as desired. There are in the laboratory, also available for experimental work, a compound Westinghouse engine of 100-horse-power, another Ide 60-horse-power automatic engine, and a Sturtevant engine of about 15-horse-power. There are, further, two pumping engines and three Worthington pumps under the control of the department. These may be used experimentally. The five tubular boilers of 80 horse-power each, which are used to supply heat and power, have been set with reference to experimental work, and there is also a

water tube boiler of 150-horse-power capable of carrying 300 pounds pressure. This is devoted exclusively to laboratory practice. These boilers are so arranged that the water evaporated may readily be measured, the coal weighed, the flue gases collected, and temperatures taken at different points in the stack. They are connected with the experimental engines in such a way that any one may be used with the certainty that no leakage will take place into the rest of the system, thus enabling the experimenter to test accurately the amounts of evaporation and consumption. A number of calorimeters are in use. The condensers are placed in the hydraulic room, where tanks are provided upon scales for weighing the condensed steam. For the purpose of testing hydraulic motors there are to be in this room a number of motors, and a stand-pipe is arranged so as to make it possible to easily vary the head of water. The testing of pumps, injectors, inspirators, etc., is also provided for, the equipment for this purpose consisting of Blake and Worthington pumps, and a number of inspirators and injectors, such as the Hancock, Sellers, and Penberthy. Then there are numerous gauges, engine indicators, revolution counters, an Edson recording gauge, pyrometers, thermometers, etc. For lecture room illustration the department has a working Corliss engine model, a working model of a Meyer valve gear, pumps in section, a Stephenson link motion model, and a large number of others.

LOUIS E. REBER, M.S.

LIEUT. JOHN PEMBERTON.

The college buildings are heated by a gravity system from a central plant, the steam pipes being carried through a tunnel five feet in the square, arched over, and twenty-three hundred feet long. The electric light wires, also, are placed in this tunnel, and are thus of easy access and entirely out of sight. The steam plant, for power and heat, of five hundred and fifty horse-power capacity, the electric light plant of over two thousand 16 candle-power light capacity, and the water plant of about two thousand gallons per hour capacity, are all in the engineering building, and available for experimental purposes.

Prof. Louis E. Reber, M.S., who is at the head of the department of mechanical engineering, is a graduate of the class of 1880 of the Pennsylvania State College. In 1881 he pursued graduate work at his Alma Mater, at the same time being instructor in mathematics. In 1884–5 Prof. Reber took advanced work at the Massachusetts Institute of Technology and Johns Hopkins University, and in 1886 returned to the College and was placed in charge of the mechanic arts department. Three years later the chair of mechanical engineering was created, and he was appointed to full professorship, which position he has since held. In 1889 he was Pennsylvania Commissioner at the Paris Exposition, and last year was Assistant Executive Commissioner of the World's Columbian Exposition in charge of the department of mines and mining of Pennsylvania, and Judge of Awards in the department of machinery. Prof. Reber is a member of the American Society of Mechanical Engineers, of the Society of Naval Architects and Marine Engineers, and of several other institutions.

WM. MASON TOWLE, B.S.

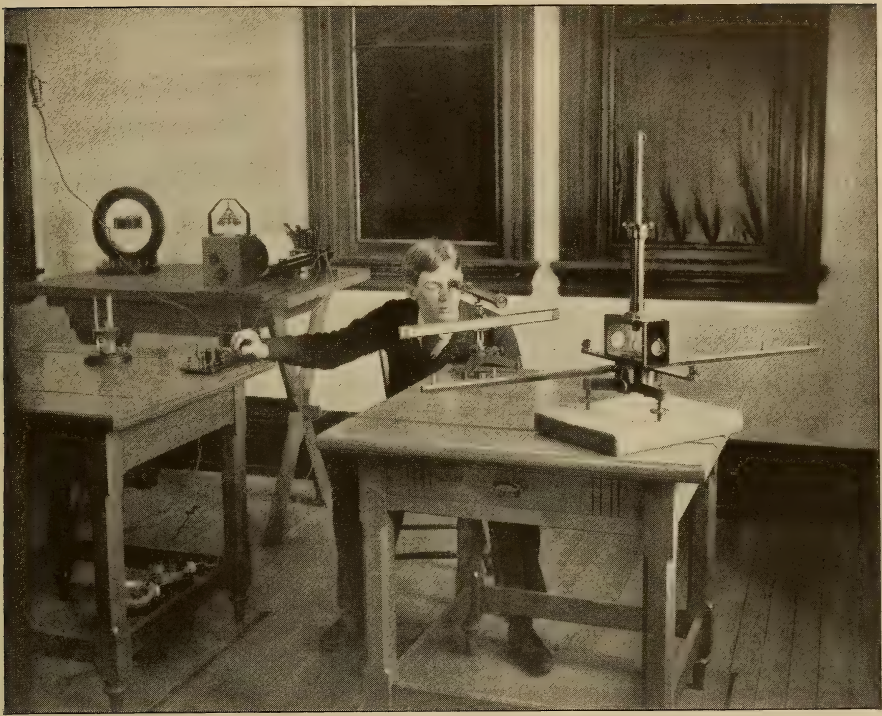
Lieut. John Pemberton, C.E., associate professor of mechanical engineer-

ing, is a graduate of the U. S. Naval Academy, class of 1862 He has seen considerable sea service, has twice been a member of the U. S. Board of Examining Engineers, and was detailed to his present position in 1890. Lieut. Thos. W. Kinkaid, assistant professor of mechanical engineering, graduated from the U. S. Naval Academy at Annapolis in 1880, and, after service on North Atlantic and West Indian stations until 1886, was detailed to the New Hampshire State College to organize the department of mechanical engineering there. In 1889 he cruised in Alaskan waters on the U. S. gunboat Pinta, and in 1891 was detailed as assistant inspector of naval machinery at Cramp's shipyard at Philadelphia. Commissioned as passed assistant engineer in 1892, he was detailed to the Pennsylvania State College early in 1893. Wm. Mason Towle, B. S., instructor in mechanical engineering and foreman of shops, graduated at the Worcester Polytechnic Institute in 1877. Prior to coming to the Pennsylvania State College, in 1892, he was foreman of shops at the Rose Polytechnic Institute in 1886 and instructor in mechanical engineering at Sibley College, Cornell University, in 1891. H. E. Dunkle, B.S., instructor in mechanical drawing, is an alumnus of the institution, class of 1893.

I. THORNTON OSMOND, M.S.

The department of civil engineering formerly occupied crowded quarters in the main college building, but at the opening of the last collegiate year it was transferred to the new Engineering building, where additional space can be advantageously employed. The theory and a portion of the practice are taught by text books, lectures, thesis and work at the drawing board, by field

WOOD TURNING.



MEASURING MAGNETIC OSCILLATIONS.

and shop work, model construction, and visits to points of engineering interest. Analytical and graphical methods are developed coincidently, so as to accustom the young engineer to choose intelligently the methods to be used, or when and how combine them. Among the subjects to which considerable time is devoted at periods during the course are sewerage and drainage, hydraulic engineering, river and harbor improvements, and the economics of roads and railroads. In order to familiarize the student with the legal forms used in connection with every engineering work of prominence considerable time is given to engineering specifications and contracts. Although methods of practical work and rapidity in executing them can be learned only from experience, yet there is much of the routine ot work of the engineer in field and drawing-room that can be brought within the scope of the student's practical training, and his work is arranged with reference to this fact.

T. R. BEYER, C.E.

The college is so situated that the operations of surveying can be carried out on a large scale, and thus made practical in a marked degree.

In latter years this practical work of the course has been extended so as to include hydraulic measurements, and for this purpose a special laboratory is now fully equipped with all the necessary apparatus. Excellent means for practical experiment in testing iron, steel and cement, afforded by the spacious apartments in the new building, add greatly to the benefits to be derived from the civil engineering course.

Fred E. Foss, A.B., Bates College,

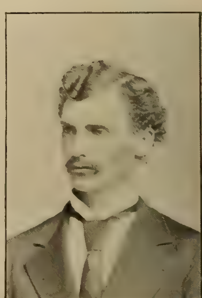
1883, for several years resident engineer of the Chicago, St. Paul and Kansas City R. R., was called to the chair of civil engineer of said college in the fall of 1893. T. R. Beyer, C. E., of the class of 1889 of the University of Pennsylvania, is instructor in civil engineering. The course of Electrical Engineering has been developed here, as in so many other colleges, in the department of physics. Until the beginning of the last college year it was carried on in the Physics and Chemistry building. For the advanced part of the work in physics, options of several subjects were offered from year to year, and from among these electricity was always chosen. This extension of the study of the theory of electricity soon led to the request that further electrical branches might be substituted for some of the studies of the senior year. Thus some of the chief applications of electricity were studied. For students who had taken mechanic arts practice and drawing, and had studied mathematics, mechanics and chemistry, this constituted very nearly a course in electrical engineering. It was a better preparation than many of the men had enjoyed whose work won for them distinction in the early days of the science. The course was at first designated as Physics and Electrotechnics. Additions were soon made, extending it to a full course in electrical engineering, furnishing a thorough training on the various subjects, theoretical and practical, properly included in an advanced technical course for those who wished to prepare themselves for work in the numerous and rapidly increasing and extending applications of electricity in modern industries. The large number of students in the course made it necessary to have more room. A separate department of electrical engineering was, therefore, instituted. The laboratory work of the course is designed to familiarize the student with the various magnetic and electrical magnitudes; to give practical knowledge of electric and magnetic measurements; and to make the student practically acquainted with the principles, construction, calibration, care and use of the best instruments in electrical engineering. It aims to include, as much as possible, practice in those problems connected with dynamos, motors, transformers, distribution of currents, transmission of energy, photometry, etc., that will be utilized in an engineer's actual work in subsequent years.

M. C. IHLSENG, E.M., PH.D.

G. G. POND, PH.D.

J. P. JACKSON, M.E.

The rooms at present assigned to the department are a portion of the large experimental laboratory, a dark room about 20' x 20' for the more delicate work, two large lecture rooms, with a seating capacity of 75, and two drawing rooms in conjunction with the mechanical engineering department. The dynamo equipment, including the light and power plant, consists of eight continuous current dynamos, ranging from 2 to 60 K. W. capacity; eleven motors, including street railway apparatus, ranging from 3 to 20 horse-



M. M. GARVER,
ASS'T PROF. PHYSICS.

IN THE PHYSICAL LABORATORY.

power; one single phase 20 K. W. alternator; one two-phase 5 K. W. alternator, and a one horse-power two-phase motor. There are also a number of transformers. These machines include a large variety of types. The laboratory equipment includes a Lord Kelvin balance, electrometers, galvanometers, dynamometers and other necessary instruments.

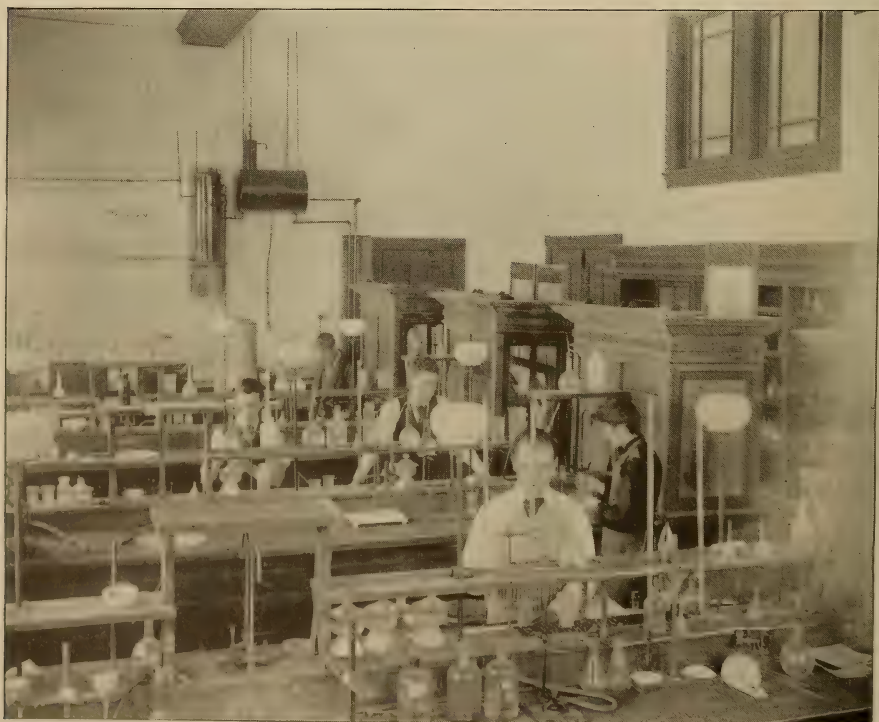
H. H. STOEK, B.S., E.M.

I. Thornton Osmond, M.S., M. A., professor of physics, is a graduate of Mount Union College. After graduation he continued his studies at Cornell University, and in 1879 was called to the chair of physics at State College. He is at present one of the State meteorologists and a member of the American Association for the Advancement of Science.

J. P. Jackson, M.E., assistant professor of electrical engineering, is a graduate of State College. In 1887 he was foreman for the Western Engineering Company, at Lincoln, Neb. In 1889 he was appointed foreman of the Edison Illuminating Company, and in 1890 he was elected director of the Mechanical Department at Fisk University, Nashville, Tenn. In 1891 he resigned this position to accept that of inspecting and constructing engineer for the Sprague and Edison General Electric Company. In 1892 he returned to his Alma Mater as instructor in mechanic arts and, at the same time, continued a line of study leading up to the degree of mechanical engineer, which was conferred in June, 1892. He entered upon his present position in September, 1892, and was put in charge of the department of electrical engineering in June, 1893. He is a member of the Ameri-

can Institute of Electrical Engineers. The newly established course in mining engineering is designed especially for students who intend to become mining engineers and surveyors, or experts in metallurgical and technical chemistry. The course covers four years, and while the studies of the first two years differ but slightly from those in the other engineering courses, the last two years are occupied with the branches and accompanying laboratory practice peculiar to the course. Special attention is given to the subject of mining in general, and the mining legislation of Pennsylvania in particular. The situation of the college is surprisingly favorable for the study of practical mining operations. Indeed, few mining schools in the country are better placed, located, as it is, in the geographical centre of the State, with anthracite coal mines forty miles to the east, and bituminous coal mines twenty miles to the west of it; with zinc, lead, iron, steel, and all the industries which have made the wealth of Pennsylvania, not half a day's journey from the college; and mining and ore washing plants only a few miles away. The department possesses a large supply of mining tools and machines, and is also erecting a working ore dressing mill. There are two perfect working models of coal washing plants, besides a typical concentration mill for lead and silver ores, operated by steam. The museums are made necessary adjuncts for the technical instruction. They embrace the collections of the first and second geological surveys of the State, besides recently purchased collections of fossils and rocks. The mineralogi-

H. J. WATERS, B.AG.



THE CHEMICAL LABORATORY

cal cabinet includes nearly ten thousand specimens of minerals and ores. The metallurgical collections embrace contributions from nearly all of the lead, zinc, and precious metal smelters of the United States, and from many of the prominent iron and steel works. These are classified for use by the students, and are so arranged as to supplement the class-room work. There are also a large number of sectional models of the best types of furnaces, blast stoves, regenerators, and refineries. A summer school course is required for the purpose of visiting mines and other places of interest in this line. At the termination of the four-year course, the college grants the degree of Bachelor of Science in Mining Engineering, B. S.; the degree of Engineer of Mines, E. M., is awarded only after an apprenticeship of five years in active life. Magnus C. Ihlseng, E. M., C.E., Ph.D., late of the Colorado School of Mines, is in charge of the department, and is assisted by H. H. Stoek, B.S., E.M., formerly of Lehigh University. In addition to the class room and practical work of the department, Professor Ihlseng is engaged in issuing a bi-monthly publication, known as The Mining Bulletin, the object of which is to collate the latest and best information pertaining to the several branches of the mining industry, and to report such investigations as may be of interest to the mining profession.

W. H. WALKER, A.M., PH.D.

The rapid development of the work in the several engineering departments within the last few years accompanied by an equally important extension of the work in free-hand and industrial drawing, and the ever increasing demand for skilled draughtsmen and designers

THE INDUSTRIAL ART DRAWING ROOM.

in all the industries effected the institution, in 1890, of a course in industrial art. Instruction in this subject, however, is not confined to the technical courses, but, on account of its great value as a means of training, the perceptive faculties, and its almost countless applications in every art and trade, it is allotted a considerable portion of the time in every course. The new course has met with unexpected success, and has grown so popular that provision has been made for a distinct department for those who wish to study art in its application to industry, or to follow it as a career. The more important features of the work include designing for carpets, pottery, glass, wall paper, metal work and bookbinding. Miss Redifer, a graduate of the Pennsylvania Museum School of Industrial Art, is placed in charge of the course. Miss

H. P. ARMSBY, PH.D.

THE AGRICULTURAL EXPERIMENT STATION.

Redifer's preparation at the museum was supplemented by study abroad.

The increasing demands for instruction in the science of chemistry led the college to erect, in 1889, a spacious building, part of which is occupied by the department of physics and part by the department of chemistry. The chemical portion comprises three floors, each sixty feet by eighty feet, and in convenience of arrangement and standard of equipment this department equals, if not surpasses, like departments in other institutions of similar nature. On the ground floor is the mineralogical laboratory, occupying a room twenty-five by thirty-five feet. and fitted up for determinative mineralogy. Directly in the rear of the laboratory is the assay room in which, by means of a plant of powerful gas furnaces, all the ordinary assays can be accomplished. The organic laboratory, thirty by thirty feet, is also on this floor, and from it opens a small weighing room and combustion laboratory, suitable to meet the wants of students in organic work. The remainder of the ground floor contains the fan room, supply room, and a small supplementary laboratory designed for gas analysis. The fan room is the source of ventilation for the laboratories. On the second floor are two large lecture rooms, one of them with a seating capacity for eighty students, and exceptionally well fitted up for every kind of lecture experiments. A moderate sized tank at the end of a twenty-foot lecture table affords convenient means for experiments in pneumatic chemistry. An additional feature of the room is a large and delicate Rübrecht balance for

W. A. BUCKHOUT, M.S.

weighing gases. This piece of apparatus is capable of showing differences in weight between air of different temperatures, and is one of the few that have thus far been imported into this country from Germany. The smaller lecture room, with a seating capacity for forty students, is similarly equipped, and contains an unusually fine collection of organic compounds, prepared at considerable expenditure of time and labor. Over five hundred of these specimens, all of which were prepared by students, were on exhibition at the Columbian Exposition. The third floor is the laboratory floor proper, for here both the qualitative and quantitative laboratories are located. The former accommodates eighty students and the latter thirty-six. Each student is given five feet of desk space, and is provided individually with gas, water, access to drain, and a full set of reagent bottles. As all chemistry centres about the balance, the room where the delicate manipulations of weighing are performed, it is of especial interest. This opens from the quantitative laboratory, and the balance shelf, resting on piers built out from the solid brick wall, carries eight of the most improved balances, which can be used without the slightest tremble caused by the movements of the heavy machinery in the basement. It is doubtful if there is a student's laboratory anywhere in which a student can have more done for him, more attention paid to his wants, more convenience in instruction, or greater opportunities for healthful self-development as a chemical student and as a practical, technical man, than in this department of the college. Professor G. G. Pond, a graduate of Amherst, is in charge. He received a thorough training for his work at the University of Göttingen and as instructor at his Alma Mater. In 1890 the degree of Ph. D. was conferred upon him by Amherst, and in the same year he accepted the chair of chemistry at State College, where, through his untiring efforts, the department ranks second to none in the technical schools of America. He is ably assisted by W. H. Walker, Ph.D. (Göttingen), who, in addition to being instructor in chemistry, is at present in charge of the department of mineralogy. During Dr. Pond's absence in Germany, F. E. Tuttle, Ph.D., is in charge of the department. In accordance with the purposes of its founders and terms of its original charter, the college gives special attention to agriculture, both theoretical and

E. J HALEY, A.M.

WM. FREAR, PH.D.

LABORATORY AT THE AGRICULTURAL EXPERIMENT STATION.

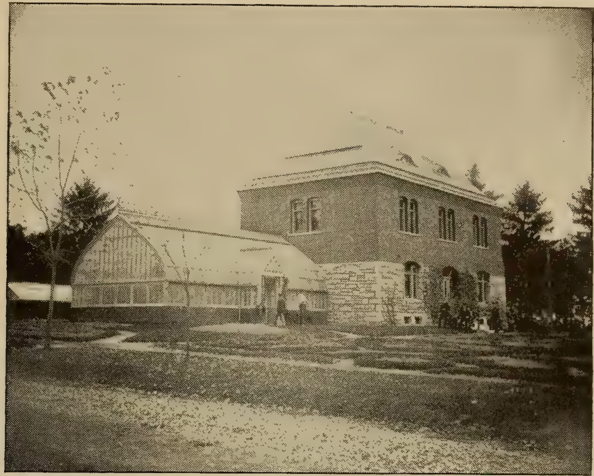
experimental, and with all the recorded development of the more purely technical courses, it is doing, to-day, more in the direction of progressive and scientific agriculture than ever before. The constant object is to teach the student how the leading branches of physical and natural science are applied to agriculture, and to afford a thorough and comprehensive knowledge of its principles and methods. Practice is combined with theory whenever the processes involve skilled labor, as in the manipulation of complex machinery, the manufacture of dairy products, etc. The direct application of science to agriculture is taught from the beginning of the course. The consideration of purely technical subjects is more exhaustively taken up during the last two years after the student has gained a sufficient basis of general knowledge. The management of the college farm is such as is sanctioned by the teachings of science and practice. Of this management in its various details the student is constantly observant and takes part in the actual labor to the extent necessary to thoroughly familiarize him with the more complex operations. This department is under the supervision of H. J. Waters, B. Agr., a graduate of the University of Missouri. Previous to accepting the chair of agriculture at the college in 1892, he was secretary of the Missouri State Board of Agriculture and assistant-agriculturist of the Missouri Agricultural Experiment Station. An important correlative in the agricultural school of the college is the agricultural experiment station, situated in the extreme northern part of the campus. The present equipment includes the station building proper, fitted up with offices, reading rooms and agricultural museum, two large laboratories and adjoining store, preparation and balance rooms, and a

LIEUT. E. W. MCCASKEY.

G. C. BUTZ, M.S.

INTERIOR OF THE CONSERVATORY.

photographic dark room. A farm of 100 acres is devoted to experiments upon crops, soils, etc., and the results of these experiments are published in bulletins and distributed free by the station. The officers of the station are: Director, H. P. Armsby, Ph.D., formerly professor of agricultural chemistry at the University of Wisconsin, and chairman of the committee in charge of the exhibit of agricultural experiment stations at the World's Fair; vice-director and chemist, Wm. Frear, Ph.D., formerly assistant chemist United States Department of Agriculture; botanist, Wm. A. Buckhout, M.S., late secretary of the Pennsylvania Forestry Commission; horticulturist, Geo. C. Butz, M.S.; agriculturist, H. J. Waters, B. Agr.; assistant agriculturist, W. H. Caldwell, B.S.; assistant chemists, W. S. Sweetser, B.S.; J. A. Fries; Jno. W. Fields, B.S.; E. J. Haley, B. S., A. M.; and M. E. McDonnell, B. S.; superintendent of farms, W. C. Patterson.



BOTANICAL BUILDING AND CONSERVATORY.

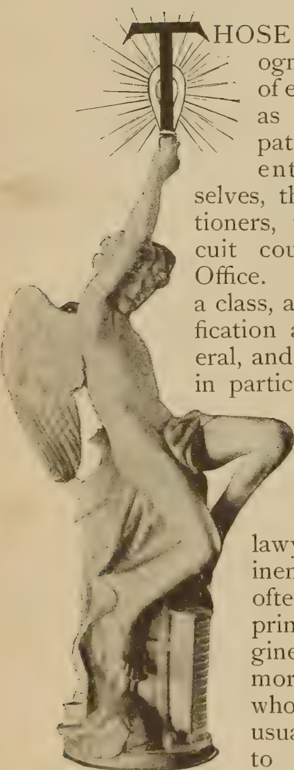
W. H. CALDWELL, B. S.

In addition to the technical courses enumerated and described, there exists the military drill and discipline which furnishes, as it were, the brawn for the healthful growth of the brain. The military organization, in command of First Lieut. E. W. McCaskey, 21st Infantry, U. S. A., consists of the entire student body as a batallion, divided into four companies, with their respective cadet captains.

All the necessary territory for the various military manœuvres is readily afforded by the large campus, and in winter the spacious armory is utilized as a drill hall. The National Government has furnished the College with two field pieces of modern pattern and a large number of cadet rifles similar to those used at West Point. By a recent law of the State, commissioned officers of the battalion are eligible to appointment as brevet second lieutenants in the National Guard. Being a State institution, in case of riots or war the corps of cadets may be called into actual service if so ordered by the executive.

ENGINEERING KNOWLEDGE IN PATENT PRACTICE.

By Edward P. Thompson, M. E.



THOSE who have always recognized the importance of engineering knowledge as a qualification of the patent attorney are patent attorneys themselves, the general law practitioners, the judges of the circuit courts and the Patent Office. Those who do not, as a class, appreciate such a qualification are inventors in general, and engineering inventors in particular. It is surprising that engineering inventors entrust their first, but not second, invention and patent case to the mere lawyer who may be eminent as such, but who is often void of even the first principles and facts of engineering science. The more honorable lawyer who is thus approached usually refers the inventor to a patent attorney equipped with the proper knowledge and experience, or else becomes responsible for thorough work by engaging a patent attorney to do the work which he himself is expected to perform. An axiom as to the necessity of engineering patent attorneys is, that all prominent and successful patent attorneys of late are versed in theory and practice of the physical sciences and engineering. An analysis of the various phases of patent practice, accompanied by illustrations from actual patent cases, serves to exemplify the utility of engineering knowledge in patent practice.

One of the first duties of the attorney consists in becoming acquainted, in the course of one or two consultations, with the invention which is about to be patented, if possible, and to become in that short time so well posted that his knowledge of the invention excels or, at least, equals that of the inventor. The inventor may have spent days and months meditating and experimenting, and he certainly is supposed to know more about the invention than any one else; still, the patent attorney is expected to know the invention better than the inventor. This may seem exaggerated, but the case is somewhat similar to that of a physician who must be better acquainted with the disease than is the patient. Humphrey Potter, as a boy, invented the automatic valve gear, but he would not have possessed enough knowledge of the steam engine to draw up a specification. In fact, all he knew was that, whereas he had been obliged to operate the valves by hand, he made an invention whereby the engine took care of itself; further than this he knew little or nothing about steam engines.

Similarly, inventors generally know their invention, but often know nothing about engineering outside of the particular elements of the invention. Before the patent attorney can write the specification, therefore, he must have more engineering knowledge, often, than the inventor can supply. Even when the latter is himself an expert engineer, a difficulty arises, provided he undertakes to describe the invention to the mere civil lawyer. The latter will not be able to understand such technical terms, as bevel-gear, spur-wheel, epicycloidal, spline, potential, armature, core, electrolysis, and so on. These and similar words should be as simple as A B C to the lawyer, or else he can, at the best, obtain only a crude

idea as to the nature of the invention. If, on the other hand, the engineer explains the machine to the common-law practitioner, in popular language, another difficulty, equally great, will present itself, which brings us to the next step in patent practice, namely, the drawing up of the specification and claims. How can such a lawyer write a proper composition without technical terms? He might as well try to be a worthy contributor to an engineering periodical or to write acceptable papers for our national engineering societies. He might expect to succeed better there than before the Patent Office, where specifications are not read for instruction only, but are required to pass an exhaustive examination by expert examiners, who are noted for exercising freely their right to criticise not only the merits of the case, but also to report upon the question as to whether the invention is described in such full, clear, concise and exact terms, as to enable a person skilled in the art or science to which the invention or discovery pertains, or with which it is most nearly connected, to make, construct, compound, and use the same. In some cases the mechanism is so complex as to require from ten to twenty sheets of drawing. The mere lawyer can scarcely be expected to read the simplest drawings, knowing nothing about the meaning of sections, plans, convex and concave shading, projections and arbitrary rules by which drawings are made and read. How much less, therefore, can he plan such drawings for the draughtsman, and describe in the specification the construction and operation of the mechanism by reference to the finished drawing!

Next come the claims. These are for the purpose of setting forth, in predetermined forms, the gist, not only of the broad idea of the inventor, but also concentrated definitions of the particular mechanisms for carrying out the idea. This is generally more than the inventor is able to accomplish. It is the work of one who has a wider scientific and engineering knowledge and who can command a higher and more polished technical language than either the inventor or the exclusive lawyer. Successive claims shade off into more and more specific statements. In a certain case—that relating to the Mergenthaler machine for setting up type—the claims numbered seventy-four, while the various modifications required many patents, containing in the aggregate many hundred claims. The following statements are claims from two patents, of which the applications were pending simultaneously. The inventions are the same. If the second claim had been as broad as the first an interference would have been declared and the inventors would have had a chance to prove priority. As it is, the owner of the patent containing the second quotation below stands without protection except as to the mere detail construction.

Before quoting the claims, the nature of the invention may be briefly set forth by stating that it consists in making the main line of an electric circuit "dead" or entirely disconnected from the dynamo, when the line becomes ruptured at any point outside of the central station. The broadest claim in one patent is: "The method of operating a system of electrical distribution embodying an electrical generator in circuit with a main line, consisting in automatically electrically separating the poles of the generator from the main line, when the latter becomes ruptured." The broadest claim in the other patent reads: "The combination, substantially as described, of a source of current of dangerously high tension, a series of translating devices in a metallic line circuit or connection leading from one pole to the other of the source and liable to breakage, disconnectors placed respectively between the two poles or terminals of such line and the electric source, and normally held in closed circuit position, and two controller magnets, one for each disconnector, placed in the charged line circuit leading from the source through the translating devices, and between opposite poles of the source and opposite terminals of the series of trans-

lating devices respectively, and retractors tending to operate the disconnectors and adapted to cause the circuit to open when the conducting line is broken at any point in the series of translating devices.'' The principle underlying the construction of claims is that the less the elements or steps, the broader the claim. The elements can be reduced to few, as in the first quotation, only by that patent attorney who is best acquainted with the invention, and he who best knows it is he who has become a scientist or engineer after long study and practical experience.

Both of these cases relate to the United States Patent law, which, however, is only a part of the law a patent attorney should know thoroughly. The patent law in all its details and with all its numerous differences in respective countries must form the tools of the responsible attorney, or else he is like a mechanical engineer who can design the foundation of a steam engine but not its mechanism. The reason is that about half of the inventions patented in the United States are patented abroad, and unless the laws of the foreign countries are known, it is more than probable that the intricate and numerous conditions imposed upon inventors by the law will be found, when too late, not to have been conformed to.

Another duty of the attorney relates to the planning and superintendence of the drawings. Prof. Trowbridge says: ''A correct drawing is generally regarded as a kind of language which conveys definite ideas from one person to another.'' The draughtsman of the patent attorney is, by incompetent attorneys, intrusted to planning the drawings, but this is an indignity to the attorney's profession. One of the rules of the Patent Office requires the limitation of the drawing to an exhibition of only that part of the device involving the invention. Neither the inventor nor the draughtsman is a competent judge in this matter. With equal reason other rules make it incumbent upon the attorney to attend to the drawings to such a degree that the draughtsman merely executes the sketches and instructions of the attorney to the same extent that the stenographer prepares the specification in typewriting after taking his notes. Therefore, the ''correct drawing,'' alluded to by Prof. Trowbridge, must be the language rather of the attorney than of either the inventor or the draughtsman. A faulty drawing, the result of ignorance on the part of the attorney of the importance of presenting both side elevations of a device, assisted indirectly in the prosecution of a patent case. It is not known, and, perhaps, never will be proved, whether or not the side elevation not shown was a real anticipation of the later invention. No one can know, from seeing one side of a house, whether or not the other side has the same color. The probability, of course, is that the color is the same, but probabilities are unknown quantities in matters of law. So with the drawing in question. It was held that the device from which the drawing had been made long before had a bow-shaped spring, but as no proof existed this feature in the latter case possessed novelty.

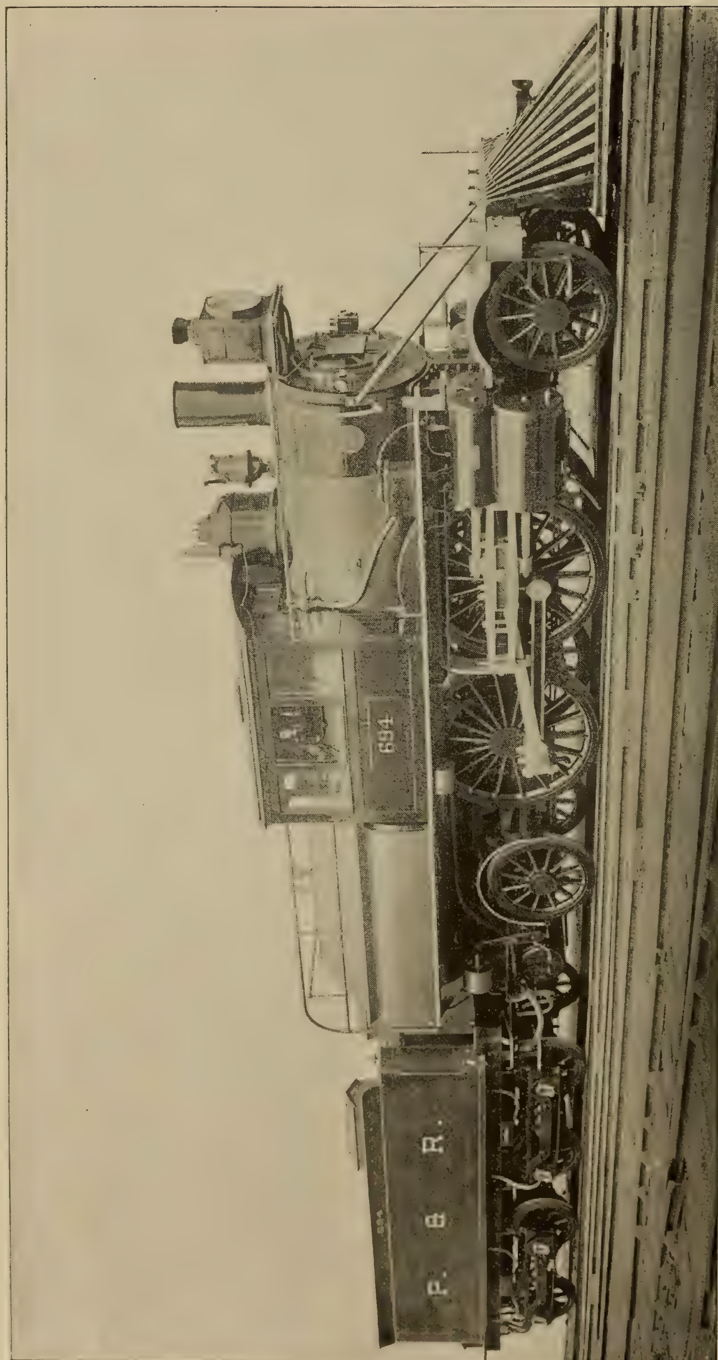
The attorney has now passed the four stages and arrives at the most difficult, that of studying and comparing the patents to which he may be referred by the Patent Office. Imagine a counselor at law who is not expert in technical knowledge, undertaking to read from five to ten or twenty figures of drawings and many pages of specifications and claims and becoming intimately acquainted with half a dozen inventions so similar that even the United States Examiner is led to believe they are one and the same. An expert patent attorney discovers that the gist of his client's invention is not justly anticipated. By proper investigation a competent expert patent attorney discovers the difference over the state of the art and sets it forth by comparing the inventions, and he obtains proper protection for the inventor. Once, in the prosecution of a chemical invention, the examiner required that either a model be filed or the chemical reactions be formulated and explained before a final

decision could be rendered. The model was out of the question, because too much time would be wasted. The inventor was well acquainted with practical chemistry, but knew nothing about chemical formulæ. The attorney had such knowledge, and in consequence the patent was granted without wasting time in constructing and exhibiting the bulky apparatus at the Patent Office.

Mathematics is seldom a prominent feature in a lawyer's education, while it is one of the essentials at an engineering institute. On one occasion the examiner rejected a claim as functional. The claim contained the phrase, "means for increasing the pressure of the belt upon the pulleys in proportion to the tension of the taut portion of the belt." The examiner was right in pronouncing it functional, but argument of the attorney held that inasmuch as the invention was purely mathematical it must be stated in mathematical language, and if not, a claim upon the mere device for illustrating the invention would be practically worthless. The examiner apparently appreciated the argument, and the mathematical claim was allowed.

In contested cases, as patent suits or interferences, engineering knowledge comes into play more than an inventor would at first suppose. Its special use is during the taking of testimony. In one instance, during the taking of testimony in an electrical case, the inventor engaged "the most prominent lawyer in the town." The cross-examination by that lawyer consisted in asking the same questions, word for word, that were asked in the direct examination by an engineering patent attorney. It is needless to say that the latter won the case. The former was unable afterward to give the least idea or detail concerning the nature of the invention. The engineering knowledge of the attorney often has a peculiar advantage in behalf of the inventor, because the former naturally knows the present state of the art, and can, therefore, give a rather accurate opinion as to novelty. Many inventions are noted for the great number of times they have been re-invented. Expert patent attorneys know this, and can pronounce unpatentability of certain inventions upon sight. Take, for example, bricks of artificial fuel, embodying the idea of mixing waste coal dust with a cement and compressing into bricks. Since 1850 scores of applications have been filed claiming such an article. How many mere lawyers have ever heard of even the words "artificial fuel?" Some other examples are the steering of torpedoes from the shore by an electric current; the applying of screens to arrest sparks in locomotives; the igniting of explosive mixtures in gas engines by an electric spark, and the adding of numbers by mechanical means. All these and hundreds more are old to the patent attorney who is also an engineer.

While it is a waste of time and money for a patent attorney to prepare himself for general practice in law, it is unfortunate that so many are not versed in patent law, and not even in the formal requirements. Simply because a patent attorney is possessed of engineering knowledge the inventor cannot trust him. The author knows of a case where such an attorney followed the innocent instructions of his client to apply for the patent in the attorney's name. The attorney, ignorant of the patent law in this respect and intent only upon pleasing his client, did so; but, in consequence, the patent stands void. Only in the event of the death of the inventor can a substitute be the applicant. To show his client his willingness that the patent should belong to the inventor, the attorney assigned it to him; but, still, the patent is invalid. A certain attorney for a foreign inventor lost, for a time, the right to a patent in connection with an interference case, because he did not put in evidence that an informal drawing had been placed on file in the Patent Office prior to the date of invention to which his opponent was restricted. When the case was appealed by a substitute attorney this evidence was entered and the inventor regained the rights which were lost by the ignorance of the former attorney.



FAST COMPOUND PASSENGER ENGINE ON THE PHILADELPHIA AND READING RAILROAD.

THE COMPOUND LOCOMOTIVE.

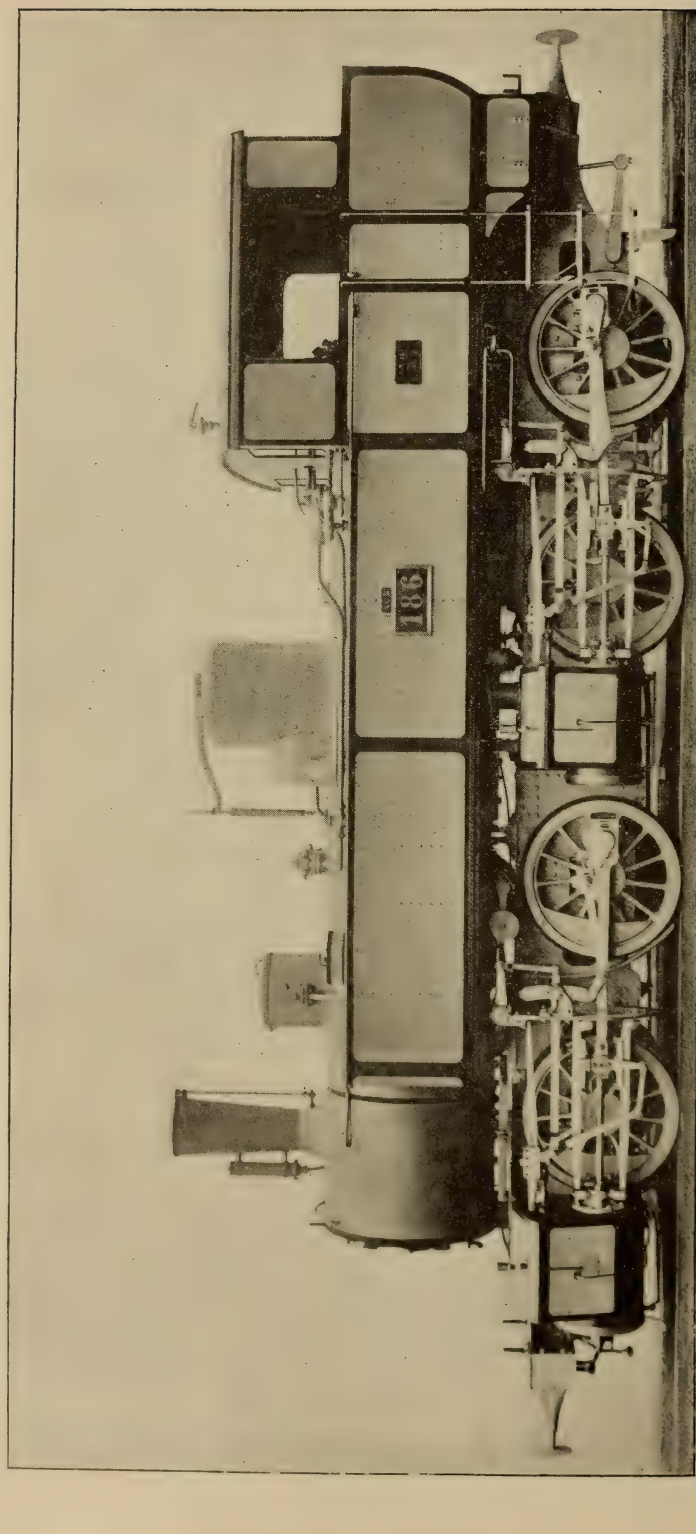
By A. von Borries, Hanover, Germany.

THE greatly extended application of the compound principle to locomotive engines within the last ten years, and the large number of different devices which have been introduced by inventors and builders, make it desirable to point out what had been done in compounding locomotives before they were brought into actual service, and what are the principle features of the various compound systems now in use. In this way it will also be possible to determine which of the various applications should be regarded as "systems" and which are only applications of the same system in a different manner.

In a paper on the subject, presented last year at Chicago before the mechanical section of the International Engineering Congress, the author undertook to treat the subject in this way, and what was there given is substantially republished here with the addition of illustrations of some of the compound engines now in current use. The first attempts to economize steam in locomotives by multiple expansion were made at an early date, and the majority were based upon the application of the principle of the Woolf steam engine to locomotives.

The earliest invention in this direction was by Mr. Roentgen, a Dutch engineer, who, in February, 1834, took out English and French patents for a "machine à vapeur expansive à cylindres independants et combinés." In his specification Mr. Roentgen proposed to overcome the difficulties of the Woolf engine by arranging the two pistons in such a manner that one was in the middle of its stroke when the other was at the end. The steam passed from the small to the large cylinder through an intermediate reservoir placed between the cylinders so as to get a more equal motion, and to prevent shocks. This reservoir may be placed in the smoke-box in order to utilize the heat of the gases for increasing the temperature and pressure of the steam. The invention was claimed as applicable to marine engines, but the inventor expected the same advantages from its application to locomotives. From this extract from Mr. Roentgen's specification it will be seen that his engine was the first two-cylinder "compound" engine; *i. e.*, multiple expansion engine with two separate cranks set at an angle of 90 degrees and with an intermediate receiver. It will also be seen that Mr. Roentgen had perfectly understood the working conditions of his engine. Probably he did not succeed in introducing his engine because there was not at that time any obvious necessity to improve the economy of marine and locomotive engines.

Another early invention which relates to the compound locomotive was introduced by Mr. John Nicholson, foreman on the Eastern Counties Railway, at Norwich, in 1847. In Nicholson's engine there were two cylinders with cranks set at 90 degrees. The steam entered the first cylinder during nearly one-half of the stroke, then by special gear a communication was opened with the second cylinder in which the piston



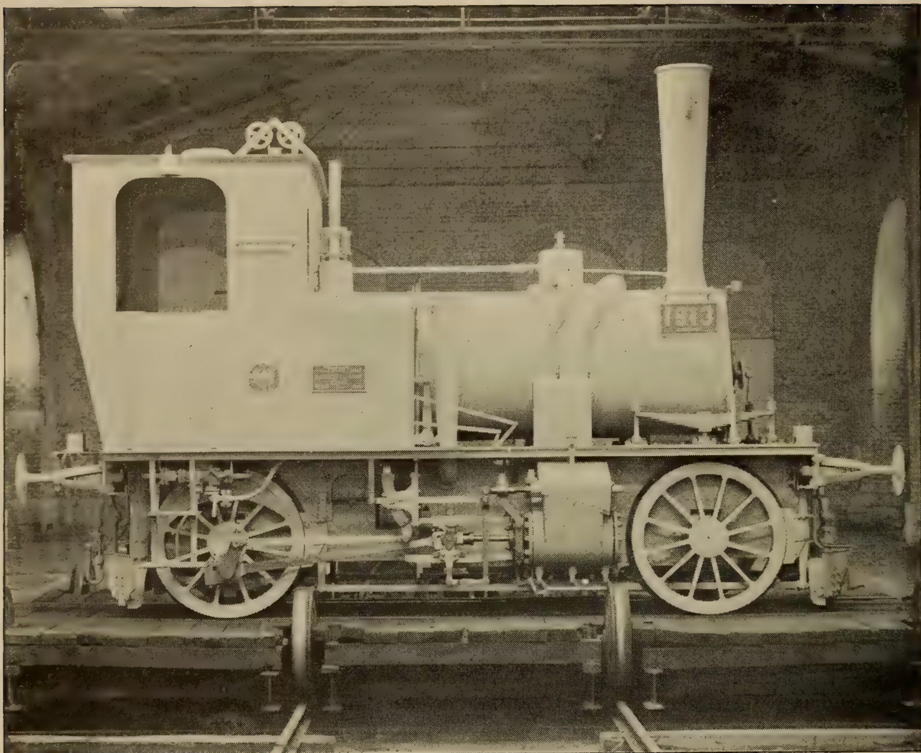
DUPLEX COMPOUND FREIGHT ENGINE ON THE SWISS CENTRAL RAILROAD, BUILT BY J. A. MAFFEI, MUNICH, GERMANY.

was at the end of its stroke, and expansion began in both cylinders. Shortly after, the communication was closed again, and the expansion continued separately in both cylinders. In the first cylinder the end-pressure was somewhat high, for the purpose of causing a strong blast. In the second cylinder expansion was utilized as much as possible. For the purpose of starting, live steam was admitted to the second cylinder by a suitable arrangement. This engine, which the inventor called a "continuous expansion" engine, worked as a compound only for that part of the steam which was expanded into the second cylinder. It might better be called a "semi-compound" engine.

In February, 1860, Mr. Ebenezer Kemp, of Dundee, invented a special arrangement of cylinders for working the steam on the Woolf principle. The low-pressure piston was set on a long plunger working on both sides in suitable smaller cylinders fixed on the covers of the low-pressure cylinder. This pair of small cylinders represent one high-pressure cylinder. The steam was distributed by one slide-valve in a similar manner to the Woolf engine. For locomotives each crank was driven by one set of cylinders. This scheme was worked out by Mr. William Kemp, chief draughtsman of the Glasgow and South Western Railway, but the locomotive superintendent refused to try it. Mr. Kemp's engine contained all the essential features of the tandem arrangement afterward introduced on a number of railways.

In 1866 M. Jules Morandières, then engineer of the Chemin de Fer du Nord (France), published a design for a three-cylinder compound locomotive for the Metropolitan Railway in London. This engine had four driving axles divided into two independent groups, the two axles of each group being coupled by outside rods. One group was driven by one inside high-pressure cylinder, the other by two outside low-pressure cylinders, all of equal diameter and stroke. For starting, all cylinders could be worked with live steam. This project was not executed. Mr. Morandières's invention was not entirely new, because in George Stephenson's English patent, dated August 10, 1846, No. 11,086, relating to locomotives with three high-pressure cylinders, the possibility of working this engine on the "Woolf" principle is mentioned. Morandières's

COMPOUND BALDWIN LOCOMOTIVE ON THE PENNSYLVANIA RAILROAD.



A GERMAN COMPOUND ENGINE, BUILT BY HENSCHEL & SON, CASSEL.

system was afterward tried in 1879 by the Struve Locomotive Works, Kolomna, Russia; and in 1877 by the Chemin de Fer du Nord, France. The latter engine was exhibited at the Paris Exposition in 1889. Mr. F. W. Webb's system of three-cylinder compound locomotives may also be regarded as a modification of Morandières's engine.

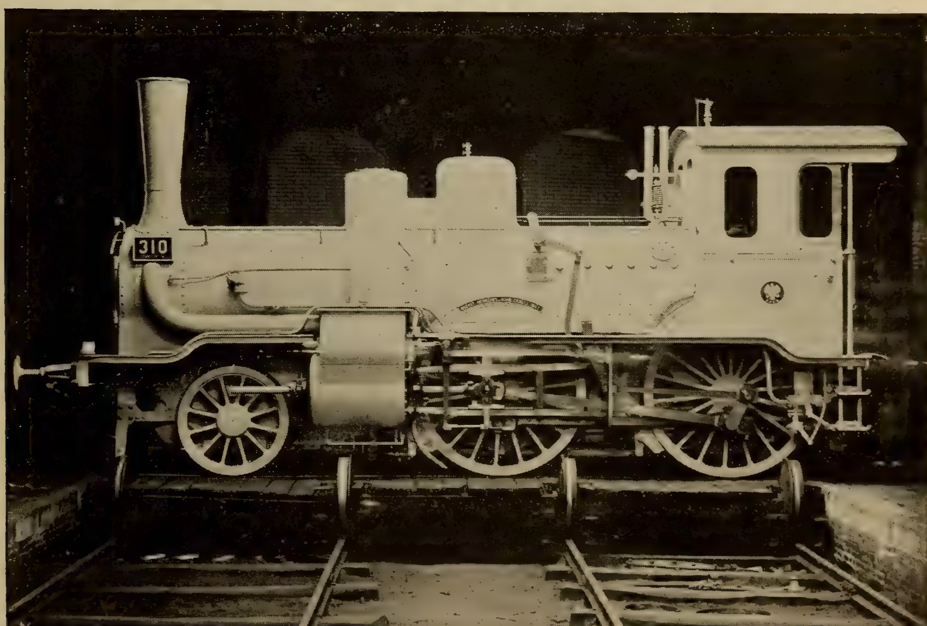
Mr. William Dawes, of Kingston Grove, Leeds, England, proposed in his patent specification of June 20, 1872, No. 1857, to expand the steam in locomotives into two pairs of cylinders, the two high-pressure cylinders driving one axle and the two low-pressure cylinders the other axle. The axles were not coupled, thus doing away with side-rods. In another scheme, all four cylinders work on the same driving axle, the two inside high-pressure cylinders on two inside cranks, and the two outside low-pressure cylinders on the outside crank-pins. For the purpose of starting, Mr. Dawes proposed to conduct live steam into the receiver by a suitable slide-valve, connected with the link-motion lever in such manner that it admits live steam to the receiver when the lever is in full-gear position. Dawes's specification contained some other modifications, with coupling chains and oscillating cylinders. In 1884 a locomotive on the Scinde, Punjab & Delhi Railway in India, was compounded in a similar manner to Dawes's proposition. Dawes's invention was the last of those relating to compound locomotives which have not been successfully introduced in practice, and it may, therefore, be said that with this the first development of the compound locomotive ceases.

Mr. A. Mallet, the French engineer, has been engaged since 1874 in adapting the compound system to locomotives. The first description of his engine was published in the Revue Industrielle of

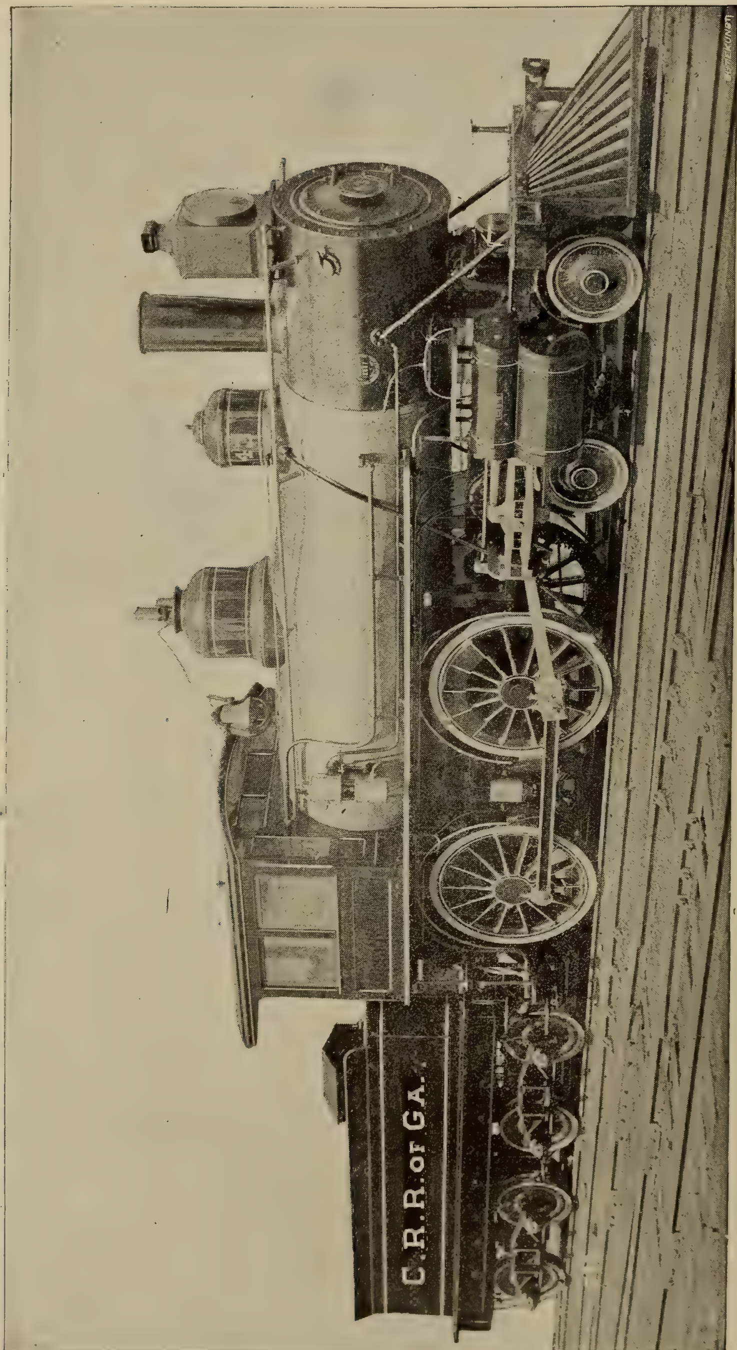
October 25, 1875. This description referred to an engine with two cylinders of different diameters working on cranks set at an angle of 90 degrees to each other. For starting and attaining a maximum tractive force on steep gradients with such moderate diameters of cylinders as would give the most economical result, Mr. Mallet proposed to work the locomotive either as a compound engine, or with live steam and free exhaust in both cylinders as an ordinary engine, at the will of the driver. For this purpose he used a special converting or change valve mounted on the smoke-box and worked by a screw from the cab. This valve was connected with both cylinders and with the live and exhaust steam-pipes in such a manner that when in one position, the steam from the high-pressure cylinder was conducted to the low-pressure cylinder, the direct exhaust from the high-pressure cylinder and the live steam to the low-pressure cylinder being cut off, the engine thus working compound. In the other position the valve opened ports admitting live steam to the low-pressure cylinder and direct exhaust from the high-pressure cylinder and closed the communication between the two cylinders, the engine thus working, with live steam and free exhaust to both cylinders, as an ordinary engine. The original Mallet system, as described, is to be classed as a two-cylinder locomotive which may be worked either as a compound or as an ordinary engine.

The special feature in the Mallet system consists in the manner of working the engine with only two cylinders of different diameters, the application of this manner of working to a three-cylinder engine having been already proposed by R. Stephenson and Jules Morandières. The first engines on Mallet's system were built in 1875 at the Creusôt Works, for the Bayonne & Biarritz Railway, and were the first real compound locomotives which proved successful in ordinary service, so that Mr. Mallet has the credit of having really introduced the first compound locomotives.

In the following years some engines for French, Austrian, and Russian railways were built or transformed on the



ANOTHER GERMAN COMPOUND.



VAUCLAIN COMPOUND ENGINE ON THE CENTRAL RAILROAD OF GEORGIA, HAULING THE FASTEST TRAIN IN THE SOUTH.

Mallet compound system, but, notwithstanding that the engines proved more economical than those of ordinary type, they were not generally introduced by the railways, probably because they were still not simple enough in construction and handling. The first engines had double handles for reversing gear, which could be coupled together for shunting, but had to be worked separately when running. The economical working of the engines thus depended upon the intelligence of the driver. In 1884 Mr. Mallet introduced a slide mechanism to avoid this double handling, and to get the proper proportion of cut-off in both cylinders automatically. In the first engines constructed for the Bayonne & Biarritz Railway, the low-pressure piston received the full steam pressure when working non-compound, thus giving very unequal tractive force and causing the train to shake at slow speeds. Mr. Mallet remedied this by putting a reducing valve in the change-valve casing for the purpose of reducing the steam pressure for the low-pressure piston in proportion to its larger area and thus securing nearly equal working of both pistons, but this added another moving part to the engines. As the change-valve was subject to the full steam pressure, it was very difficult to change the motion after starting. To obviate this, Mr. Mallet, in 1884, introduced a double valve governed by a piston, which was easily worked by a three-way cock from the cab.

For the purpose of constructing powerful goods engines Mr. Mallet proposed, in 1879, a four-cylinder arrangement, the high-pressure cylinders being fixed on the front covers of the low-pressure cylinders. In another scheme he proposed to replace the low-pressure cylinder by two cylinders in one casting and worked by one slide-valve.

In 1880 the author, then engineer of the Prussian State Railway at Hanover, encouraged by the economical results of Mallet's locomotives, proposed to simplify the construction and handling of the two-cylinder compound locomotive by using only live steam in the low-pressure cylinder for starting and one handle for the reversing gear, the proper proportions of cut-off in both cylinders being made by the gear itself. The first locomotives on this system were two small omnibus engines, built at the works of F. Schichau, Elbing. For starting, they had a small port in the face of the regulator, which was opened and passed live steam into the receiver when the regulator was full open. The link motion was of the ordinary kind, giving equal cut-off in both cylinders. This arrangement not being fitted for larger engines, the author proposed to admit live steam of reduced pressure into the receiver through ports in the double regulator valves and faces, which could admit steam when the small regulator valve is open. For the same purpose he also patented a slide-valve coupled to the reversing gear in such a manner as to open a small communication between the high-pressure steam-pipe and the receiver when the engine is in full gear. A similar arrangement was previously proposed by William Dawes, and was afterward used by Mr. G. Lindner in the form of a two-way cock.

Instead of this arrangement the author supplied two goods locomotives, built in 1882, with small reducing valves, which, on starting, filled the receiver with steam of 40 per cent. of the boiler pressure and which could be closed by the driver after starting. The back-pressure which is exerted on the high-pressure piston by the steam in the receiver when the slide-valve happens to cover the steam port was overcome in these engines by a small check-valve which, when necessary, permitted steam from the receiver to fill up the space behind the high-pressure piston. On these engines the author also applied the differential reversing gear, which gives to both cylinders automatically the proper proportions of cut-off in the simplest manner, by setting the lifting levers on the reversing shaft at a certain angle and making the lifting links of suitable different lengths. By these means the two links are hung in such different positions that for 40 per cent.

cut-off in the high-pressure cylinder, 50 per cent. in the low-pressure cylinder is reached for running forward, which proportion was found the best. For back gear, only the full gear notch is to be used. The latter defect was overcome in 1889 by a slide link arrangement, invented by M. Kuhn, engineer to Henschel & Son's Locomotive Works, Cassel, which gives the proper proportion of cut-off both forward and backward in a similar, but simpler manner than by Mr. Mallet's method.

After some years' experience with these two goods engines, and with ten larger omnibus and four express locomotives, the author became convinced that it was not possible to get the necessary starting power by filling up the receiver, but that the full steam pressure on the high-pressure piston and a suitable reduced pressure on the low-pressure piston was needed to start fully loaded goods trains on grades, and short-coupled passenger trains at stations, without delays. He therefore introduced, in 1884, his well known intercepting valve, which, when closed by the driver, separates the low-pressure cylinder from the receiver, and opens a small communication with the main steam pipe. When the regulator is then opened, the wire-drawn steam which starts the low-pressure piston cannot enter the receiver and induce back-pressure on the high-pressure piston. After starting, the receiver is filled by the steam exhausted from the high-pressure cylinder to the same pressure as in the low-pressure valve-chest, and the intercepting valve opens automatically, shutting off the live steam, the engine then working on the compound principle.

At the same time, Mr. T. W. Worsdell, then locomotive superintendent of the Great Eastern Railway in England, introduced a similar arrangement, in which a flap intercepting valve is closed, when starting, by the live steam for the low-pressure cylinder working on a small piston. The steam is governed by a small valve from the cab, and shut off when the train is in motion. Another similar arrangement was afterward made by Mr. Busse, locomotive superintendent of the Danish State Railway.

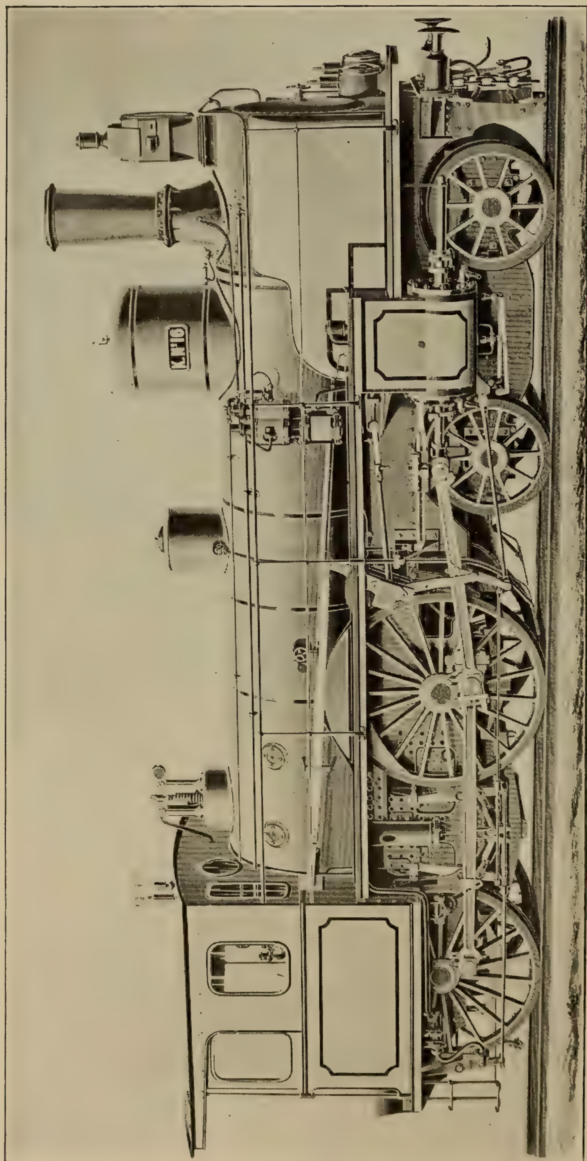
In 1887 the author added to his intercepting valve one or two small pistons, or an annular face on the rod, which were exposed to the live steam, and closed the valve automatically when starting. By this means the action of the intercepting valve became fully automatic. The Worsdell and Von Borries system, as now applied to some 1650 compound locomotives in all parts

A ROGERS COMPOUND ENGINE.

COMPOUND LOCOMOTIVE ON NORTH BRITISH RAILROAD, HAULING THE TRAIN KNOWN AS THE FLYING SCOTCHMAN.

of the world, means a two-cylinder compound engine which starts with live steam in both cylinders, and begins automatically to work as a compound when the receiver has been filled by the exhaust from the high-pressure cylinder. In this system only one handle is necessary for the reversing gear, the proper proportion of cut-off in both cylinders being regulated by the different positions of the levers on reversing shaft and different lengths of hanging links. It has been questioned if the Worsdell-Von Borries system really deserves to be classed as a "system" proper, or if it is not only a modification of Mr. Mallett's system.

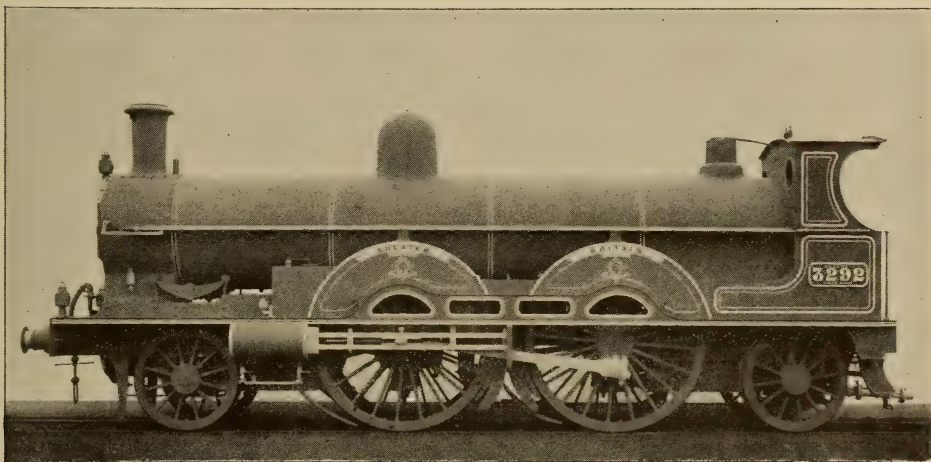
From the facts stated above, it will be clear that Roentgen was the first inventor who had proposed to work a two-cylinder locomotive on the compound principle, and that, as is well known, many stationary and marine compound engines with only two cylinders were at work before 1875. Therefore, a two-cylinder compound locomotive cannot be classed as Mallet's or another inventor's system, but is only the application of well-known principles to a locomotive. Also, as stated before, the Mallet system is characterized by the possibility of working the two-cylinder locomotive either as a compound or as a single expansion engine at the will of the driver. The Worsdell-Von Borries system is characterized by starting only with live steam in both cylinders, and automatically changing to compound working shortly after starting. Both systems differ in the most essential point, and, therefore, the latter deserves to be properly called a "system." By this statement, the credit due to Mr. Mallet for having first successfully applied the compound system to locomotives is not touched. All the numerous arrangements of the two-cylinder compound locomotives, which have been introduced since 1885, are worked on one of these two original systems, and therefore are only modifications of them.



COMPOUND PASSENGER LOCOMOTIVE ON THE ST. PETERSBURG AND WARSAW RAILROAD, RUSSIA.

The Mallet system was altered by M. Borodine, engineer-in-chief of the South Western Railway of Russia, who applied a cylindrical change-valve, and by Mr. Middelberg, engineer-in-chief of the Dutch Railway, who made the low-pressure cylinder of the same diameter, but double the stroke of the high-pressure cylinder. Another modification was invented in 1891 by Mr. Aspinall, locomotive superintendent of the Lancashire & Yorkshire Railway, England, who applied a large cylindrical four-way cock in combination with a small live steam valve, to work the engine both simple and compound. In 1892 the author introduced his double piston change-valve, in which the two pistons work as a reducing valve for the live steam passing to the low pressure cylinder.

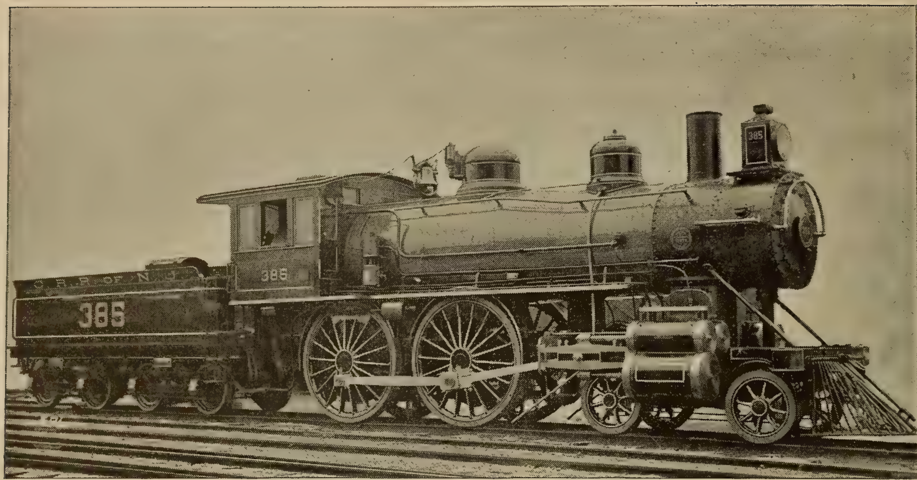
Mr. Herbert Lapage, London, in 1889 added to the Worsdell-Von Borries system an auxiliary valve, between the high pressure cylinder and the intercepting valve, by which a direct exhaust can be opened from the high-pressure cylinder; the engine can therefore be worked either on the Mallet or Worsdell-Von Borries principle. A similar arrangement was brought out in 1890 by the Rhode Island Locomotive Works, of Providence, R. I., to which the Franklin Institute, in 1892, awarded a prize as for a new system. The Worsdell-Von Borries system is also used by the Schichau Locomotive and Shipbuilding Works, Elbing, Germany, who replaced the intercepting valve by a slide valve driven automatically by pistons, and by the Schenectady Locomotive Works, of Schenectady, N. Y., who replaced it by a piston driven by suitable faces and governed by an oil brake to prevent shocks.



WEBB'S COMPOUND LOCOMOTIVE ON THE LONDON AND NORTHWESTERN RAILWAY, ENGLAND.

Mr. F. W. Dean, member of the American Society of Mechanical Engineers, of Boston, replaced the round intercepting valve by a flap valve, governed by a separate automatic reducing valve, working on the same principle as Von Borries' engines of 1882. The Brooks Locomotive Works of Dunkirk, N. Y., added to the intercepting valve a self-acting reducing appliance, to admit steam of suitable pressure to the low-pressure cylinder. The Rogers Locomotive Works, Paterson, N. J., applied an arrangement very similar to Worsdell's, but with a live steam valve controlled by the reversing gear.

Mr. Lindner, of the Saxon State Railways, wishing to dispense with the



VAUCLAIN COMPOUND LOCOMOTIVE ON THE CENTRAL RAILROAD OF NEW JERSEY.

intercepting valve for the purpose of running down grades with the reversing brake, applied a two-way cock operated by the reversing shaft, to fill automatically the receiver when the handle is put in full gear, or suitable ports in the regulator valve for the same purpose, in accordance with Dawes' and Von Borries' former projects. In order to overcome the back-pressure on the high-pressure piston when the steam ports are covered, Mr. Lindner provides small ports in the high-pressure slide valve, by which steam from the receiver fills the space behind the high-pressure piston. Later on Mr. Lindner placed the entrance of the auxiliary steam-pipe just over the low-pressure slide valve, so that live steam can enter only when one port is open. This arrangement prevents back-pressure on the high-pressure piston when this piston has to make the start. For the same purpose the Krauss Locomotive Works, of Munich, use a special small slide valve, actuated by the high-pressure motion, in combination with Von Borries' ports in the regulator valve. Mr. Klose, locomotive superintendent of the Würtemberg State Railways, combined the Von Borries intercepting valve with Lindner's arrangement. It is possible that other modifications of the Worsdell-Von Borries system may exist, which have not been brought under the notice of the author.

In 1881 Mr. F. W. Webb, locomotive superintendent of the London & North Western Railway, England, after having tried Mallet's system, introduced his well-known three-cylinder compound express locomotives. Contrary to Morandières's project, he uses two outside high-pressure cylinders which drive the trailing wheels, and one inside low-pressure cylinder for the driving wheels. In the first engines live steam was admitted to the low-pressure cylinder for starting, but in the later engines both sets of cylinders can be worked with live steam and free exhaust. The tandem arrangement, first proposed by Ebenezer Kemp, has been tried in various forms by different railways.

Mr. Mallet, in his *Mémoire* of 1877, proposed to use the four-cylinder tandem arrangement for locomotives requiring great tractive force where one low-pressure cylinder would be too large. In his communication to the Institute of Mechanical Engineers in 1879 he showed an arrangement of this kind, the high-pressure cylinders being fixed on the front covers of the low-pressure cylinders.

In 1883 the Boston & Albany Rail-

road tried this system on a passenger locomotive, but without success. At the Industrial Exhibition at Edinburgh in 1886 the North British Railway Co. showed a passenger engine with inside tandem cylinders, the high-pressure cylinders being fixed on the front covers of the low-pressure cylinders, the latter occupying the usual position under the smoke-box. The results seem to have been unfavorable, no more engines having been built of this type. At the Paris International Exhibition in 1889 the Chemin de Fer du Nord showed an eight-coupled goods engine with outside tandem cylinders, the high-pressure cylinders being placed behind the low-pressure cylinders. The latter had double piston rods carried over and under the high-pressure cylinder to the cross-head. Each pair of cylinders had only one slide valve. The results seem to be favorable, since the railway company continues to build this type of engine. Passenger engines with outside cylinders, the high-pressure in front of the low-pressure, were built by the Grafenstaden Locomotive Works for the South Eastern Railway ot Russia, and in their own workshops by the Hungarian State Railways. The results of the trials made by the latter engine seem to have been unfavorable.

In 1890 Mr. Vauclain, superintendent of the Baldwin Locomotive Works, of Philadelphia, Pa., devised a new arrangement of the four-cylinder Woolf locomotive, placing the high-pressure cylinder above or below the low-pressure cylinder, the piston rods of each pair of pistons being connected to one cross-head. The distribution of steam for each pair of cylinders is controlled by one circular valve containing four pistons with tightening rings. For starting, live steam can be admitted to the low-pressure pistons by an arrangement connected with the cylinder drain cocks. Generally, the method of working in this engine does not differ from the before-mentioned four-cylinder tandem engines, but the whole arrangement differs so much from its predecessors that it deserves to be called a "system." A similar system was introduced in 1891 by Mr. Johnston, superintendent of motive power, Mexican Central Railroad, by placing the high-pressure cylinder in the centre of the low-pressure cylinder. The low-pressure piston is therefore annular and requires two piston-rods and two sets of packing rings.

The arrangement of working one set of drivers by a pair of high-pressure cylinders and another set by a pair of low-pressure cylinders, these two sets of drivers being coupled or not, placed in the same rigid frame or in two articulated frames, was first mentioned in Mr. Mallet's *Mémoire* of 1877, and therefore these engines should be classed under the head of Mallet's system. A similar system was patented by Mr. Lapage, of London. The first locomotive of this type with rigid frame was an express engine built in 1885 by the Grafenstaden Works to the designs of M. de Glehn, engineer-in-chief, for the Chemin de Fer du Nord, France, each pair of cylinders driving one pair of driving wheels which were not coupled together. More powerful engines of the same type have been built for the same road, and with similar general arrangement for the Paris, Lyons & Mediterranean Railway, in both cases with coupled drivers. The latter engine was shown at the Paris Exhibition in 1889, together with an eight-wheeled goods engine of the same type, in which the two sets of four driving wheels were also coupled.

The first engine of the other type, with two articulated frames, of which one is fixed to the boiler and the other is movable to enable the engine to pass round sharp curves, was built in 1889 for the Decauville light railways in Faance. A number of similar engines were successfully used on the narrow-gauge railway at the Paris Exhibition in 1889. Some standard-gauge locomotives of this type have been built for the St. Gothard, the Swiss Central, and the Herault Railways, France, and a further number are being built for other railways. The number of compound locomotives of the principal sys-

tems now running may be estimated as follows :

Mallet's system	150
Worsdell's von Borries	1,650
Webb's	150
Vauclain's	200
Others	50
Total	2,200

In looking at these figures the question arises, What will be the future of the compound locomotive? The good and sometimes excellent results which compound locomotives have always given, when the principal advantages of the system have been properly applied and complicated construction avoided, prove, that for all locomotives which have to work with modern variation of tractive force the compound locomotive is the engine of the future.

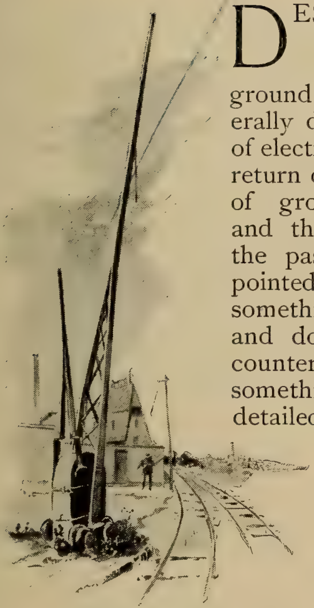
The range of variation of tractive force within which the efficiency of the compound locomotive surpasses that of the ordinary engine is not so large as is generally supposed. For unvariable compound engines (*i. e.*, engines working compound only) this range extends between the full amount and one-half of the tractive force. For engines on the Woolf principle it is still smaller. The compound locomotive will therefore be most advantageous when the tractive force is most uniform, and will give no advantage where the tractive force is very variable.

To obtain the greatest efficiency for the compound locomotive, the cylinders should be of such dimensions as to allow the engine to be worked as much as possible with the most economical cut-off, but in most cases the pistons then become too small to enable the engine to exert the full tractive force, available by the adhesion, by working compound at full gear. It is preferable, therefore, in most cases to provide for working the compound locomotive when necessary with live steam in both cylinders on Mr. Mallet's principle.

For this purpose, designs similar to those of Mr. Lapage and the Rhode Island Locomotive Works (who apply a self-acting interceptive valve in combination with an auxiliary exhaust), and the author's new change valve, are specially suited. With such arrangements the two-cylinder compound locomotive is capable of fulfilling all the requirements of ordinary railway service, and even to a great extent meeting the requirements of variable tractive force. In conclusion, the author is of opinion that the two-cylinder compound locomotive will be the railway motor of the future except in cases where an extra large amount of tractive force is required, and here Mr. Mallet's articulated four-cylinder compound engine will successfully replace the two-cylinder locomotive.

COMPLETE METALLIC CIRCUITS FOR ELECTRIC RAILROADS.

By J. H. Vail, M. Am. Inst. El. Engrs.



DESTRUCTION of gas and water pipes and underground metal work, generally due to the action of electric street railroad return currents, is an evil of growing magnitude and the development of the past few years has pointedly suggested that something must be done, and done promptly, to counteract it. What this something might be was detailed recently by the writer in a paper read before the National Electric Light Association and this, together with supplementary data, is accordingly reproduced here as of current interest and importance. The writer discovered the effects of electrolysis on pipes early in 1890 and some important investigations were then made under his direction, but for obvious reasons the results could not be made public.

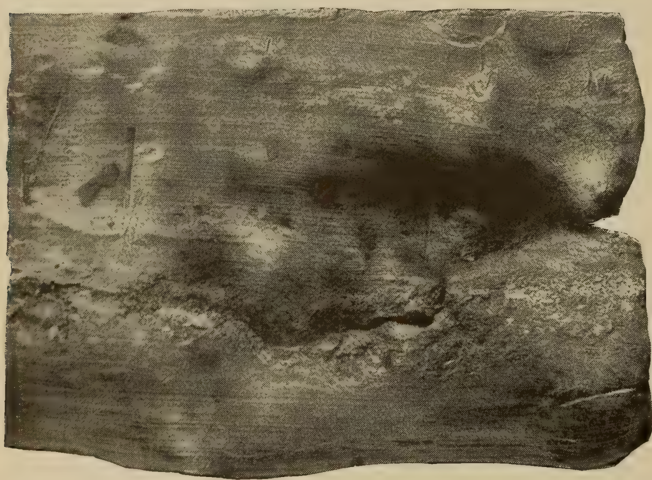
In the early days of electric railway construction two distinctly different systems were devised and competed for public favor, one being the overhead, double trolley system, affording a complete metallic circuit for the out-going and return of all the electric current required to move the motor cars, and the other being the single trolley system, using the track and earth as a common conductor for one side of the circuit, and the trolley wire and parallel mains for the opposite side. The double trolley system was found impracticable of operation in many of its details, and the single trolley, because of its simplicity and convenience, has made rapid advances in public favor. The single trolley system has depended largely upon the earth and buried pipe systems for completing the circuit.

Many devices for making the track and earth combined a more complete and low resistance circuit have been resorted to, such as burying copper or iron plates, old rails or old car wheels, and connecting same to the track; or, at frequent intervals, driving iron rods down in the earth and connecting by wires to track; or by making actual connection with wire from tracks to gas and water pipe systems. Also, for supposed reinforcement of the tracks a bare wire of iron or copper has been used, buried in the earth, laid parallel to the track, and connected at frequent intervals. Supposed electrical connection of rails at joints, by bond wires of iron or copper having only a small fractional part of the capacity of the rail as a conductor, has also been resorted to.

In the early days of electric railroad construction it was assumed by experts that the earth and the buried pipe systems would, when combined, form an ample return for the electric current. At that age of the art experts did not fully appreciate the immense quantities of current that would require to be carried, and therefore did not foresee that these currents when disseminated would produce the serious results that have been caused by electrolytic action on systems of pipes buried in the earth and owned by other companies. Frequent tests prove that the earth itself cannot afford the free path for the current that was anticipated. Earth conductivity has been overestimated.

Iron and lead pipes, being better con-

ductors than earth, must of necessity carry the current, if no superior path is offered by the method of construction. The natural moisture of the earth hastens the destructive electrolytic action of the current on these pipes. In some soils electrolysis is more rapid than in others, the rapidity of action depending upon the chemical constituents of the soil. It has been found that illuminating gas leakage held in such soils as underlie the cities of New York, Brooklyn, Boston, Philadelphia and elsewhere, hasten electrolytic action. To prove that the methods of work mentioned are still in vogue, I quote the following section from specifications recently sent out from the office of a prominent electric railroad company :



SECTION OF A TELEPHONE CABLE COVERING FROM A CONDUIT.

"Each rail shall be connected together by two bonds, made of No. 4 galvanized iron wire (Roebling gauge), to each end of which shall be brazed two nine-sixteenth inch Norway iron rivets.

"Both of the bonds shall be separately connected with a No. o galvanized iron supplementary wire, by means of No. 4 galvanized iron wire connections, which shall receive at least four turns around both the bonds and supplementary wire and be thoroughly soldered to the same. Ground plates shall be placed about 1000 feet apart. They shall be buried not less than eight feet in the ground, preferably in damp places, and two No. o galvanized iron wires shall be brazed to the ground plate and connected one to each supplementary wire in each track, by thorough wrapping and soldering. The ground plates shall be of galvanized sheet iron, two feet square and one-eighth inch thick, bent around in the form of a spiral."

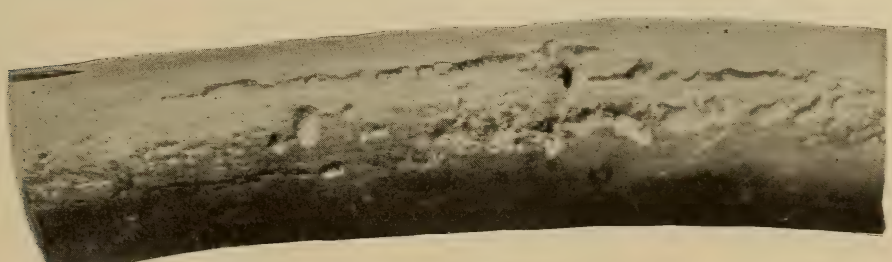
It is evident that electricians had then perfect faith in the earth as a conducting medium. Evidence had not been produced that Mother Earth was incapable of carrying the enormous quantities of current required; neither had an opportunity been afforded to demonstrate her capacity. That some still have faith in the earth's ability in this direction is attested by the above specifications and other constructions being executed at this date.

Having briefly reviewed the practice for the past few years, let us now have a look at the resultant effects. In cities provided with electric railroads destructive electrolytic corrosion is now acting upon gas and water pipes, and will inevitably produce serious impairment of all such underground pipe systems within a brief period, unless prompt measures are taken to prevent further damage. Within the past year strong evidence of damaging electrolytic action has been produced. In one case a section of iron water pipe showed complete perforation, caused in four weeks' time. Lead coverings of telephone cables also show serious damage. In another case a plumber in a city in Pennsylvania was repairing a water pipe in a house, and on breaking joint, an electric arc formed across the separating ends of the pipe. This house was not in the direct path of the railroad circuit. Investigation followed, proving beyond question insuffi-

cient electric conductivity of the track system; also that the earth did not afford a good return though the tracks were well grounded. It was found that the railroad current was traveling all pipe systems in its effort to complete the circuit to the dynamos in the power station. Actual tests were made here by an expert, using standard instruments. From 135 readings of an ampère meter it was found that the feed water pipes leading in the station carried an average current of ninety-three ampères. Further careful test proved that with twenty-three cars in operation on the system forty per cent. of the total current was carried on the underground pipe systems.

CORRODED TELEPHONE CABLE COVERING.

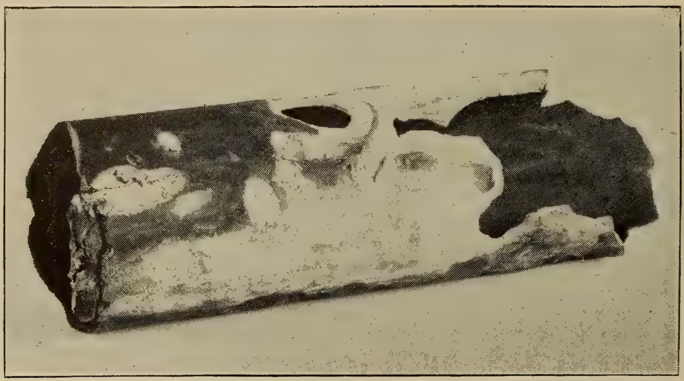
In still another case a fire occurred in a house, and after being extinguished, investigation showed that the current of the electric railroad system had been carried along the iron water pipe, and that probably by vibration causing the pipe to come in contact an arc formed between the water pipe and gas pipe, burning a hole through the gas pipe, and thus set fire to the gas. The house was saved by prompt action. A test recently made by an expert engineer developed the fact of a loss of twenty-four per cent. on the system, and a difference of twenty-five volts potential between parallel tracks opposite the power station. Prof. Barrett, in an exhaustive report to the Mayor of Chicago, states that "this destructive action is not alone confined to the lead covering of telephone cables, but is acting on gas and water pipes and almost all buried metal work," and that it can only be a question of time when more disastrous results will manifest themselves. As further and substantial evidence an illustration is given on the next page of a section of six-inch water main. This pipe was entirely corroded through by the action of the electric current of the street railroad system, which was constructed under my direction about four years ago. This effect was produced in about two and one-half years; another section was rendered useless in six months.



FROM A TELEPHONE CABLE UNDER A TROLLEY RAIL.

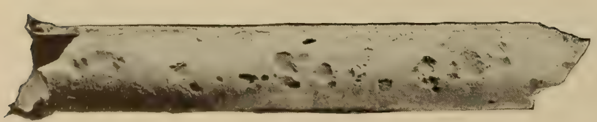
It has been stated that in an electric railroad system where a connection has been made to water pipes, the pipes have carried as much as twenty-eight per cent. of the total current. Instances

are known where as much as forty per cent. is carried on the pipe systems. It is the opinion of the writer that any gas or water pipe system used as a carrier of electric currents will not only be corroded through the body of the pipes, but will surely in due time show defects at joints, as higher resistance is encountered there than in any other portions of the pipe system. It has been proven by test that the electrolytic action of even five ampères of current on an iron pipe is considerable, and that much damage will result in one year. The rapidity of action depends upon the character of the soil, amount of moisture, and quantity of current; the destructive action is constant and sure.



FROM A 6-INCH WATER MAIN AT NEW YORK CITY.

There can be no question that a grave danger confronts us and must be surmounted. Instances are numerous, proving that the electric current is present on the gas and water pipes in buildings contiguous to electric railroad lines. Even those of us who are familiar with handling electric currents hesitate to draw a combination of electricity with our gas or water. We know that the gas and water pipes entering our houses may be charged with such a current, and that it only remains for the circuit to be completed by a possible accident through our bodies, or the occurrence of a fire by automatic action between vibrating pipes. City engineers, water companies and gas companies are placing the responsibility upon the railroad companies for the damage caused on pipes by electrolysis.



SECTION OF A WATER PIPE FROM ZANESVILLE, O.

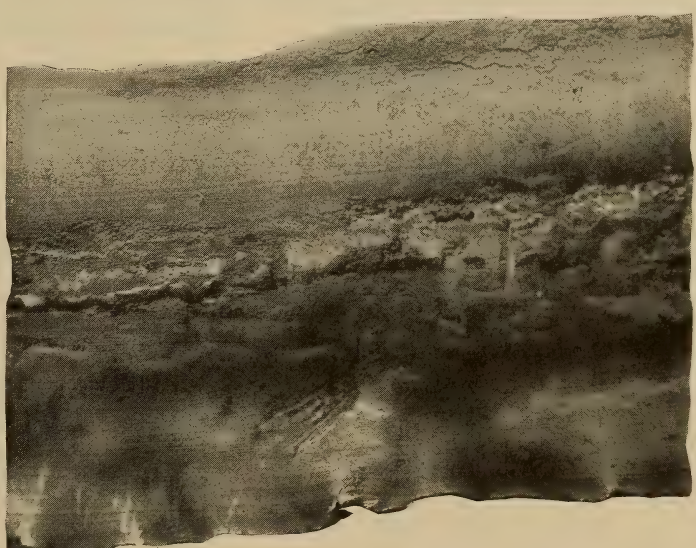
Any system using ground plates, ground rods or substitutes therefor, or bare return track wire buried in the earth, is constructed primarily to utilize the earth as return circuit; when the earth does not afford good return the current is sure to follow the water pipes, gas pipes or other buried conductors offering the path of least resistance. We now see that these prove to have been only make-shift methods to reduce the cost of construction. We find that the evidence thus produced and the troubles constantly occurring in existing street railway systems are sufficient to show that all methods of grounding the track circuit or connecting to pipe systems should be entirely discontinued; it therefore becomes of vital importance to so construct the electric railway system as to avoid all electrolytic action on buried systems of metal work that are the property of other concerns.

Having produced the evidence and established the case, let us briefly analyze the matter and ascertain the reason for these results. The whole case may be stated in the single sentence, that the electric current must under natural laws follow the path of least resistance. What was intended to be good has proved to be defective electrical work in connection with track systems, the conductivity of the rail circuit being impaired to such an extent that the electric current must force itself through the earth or through metal pipe lines buried therein. We must here diverge for a moment to show how the incandescent electric light system operated in multiple arc compares with the railroad system.

EFFECT OF ELECTROLYSIS ON AN IRON WATER PIPE ON 30 DAYS' EXPOSURE.

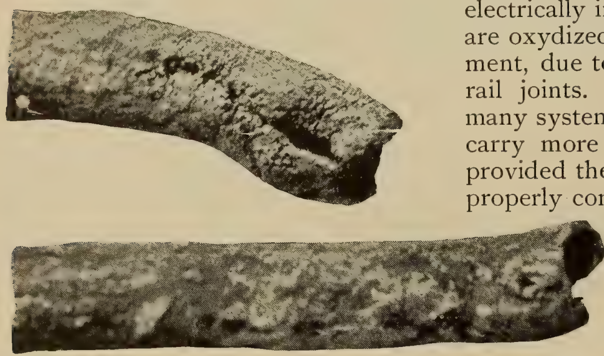
An electric railroad system may, in some degree, be compared with a system of electrical distribution for incandescent lighting, the groups of lamps in buildings connected in multiple arc, comparing with each car and its motors demanding current. The systems otherwise differ in important particulars. The load on the electric light system is not subject to such violent fluctuations as on the electric railroad, where the instantaneous demands for current and its equally prompt release must be controlled. The current required for the car is a moving load as the car progresses on its route; this and all other differences of conditions must be duly considered when laying out the system of distribution. With the electric lighting system, the current for consumption is derived from the mains, the equalization of pressure is maintained through the feeders, the mains are of equal capacity on either side of the system.

With the electric railroad the track forms one side of the consumption circuit, and must be so treated in regard to distribution of current as to utilize its carrying capacity equally with the other side, and thus equalize the delivery of current. The electric conductors composing a system of distribution for electric railroads should be so thoroughly well proportioned as to show



ANOTHER SECTION OF CORRODED TELEPHONE CABLE COVERING.

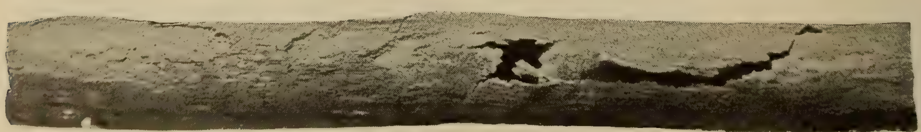
the minimum variation of pressure throughout the system, even when the entire number of cars are in operation. This equality of pressure is an important requisite for the economical working of the motors. The writer has tested electric railroad systems operating with a station pressure of from 500 to 550 volts, and showing only 300 to 325 volts on various divisions of the system.



CORRODED LEAD PIPE.

Here is a direct loss between dynamos and motor car of over forty per cent. Is it therefore any wonder that some roads report extraordinary coal consumption? Such loss in pressure indicates radical faults in the original planning of the system and the distribution of copper. When operating under low voltage, the motors demand an increased quantities of current are faulty in at least three particulars: First. Restricted conductivity at joint, due to insufficiency of the rail bonds. Second. Neglecting to properly utilize the track as a conducting medium. Third. Failure to provide a complete circuit of low resistance.

For electrical purposes we cannot regard the joint plates and bolts as of any permanent value; the contact is electrically imperfect, the metal surfaces are oxydized and under constant movement, due to passing cars pounding the rail joints. The rail sections are, in many systems, of ample conductivity to carry more than the requisite current, provided they are perfectly bonded and properly connected by feeders with the dynamos. We must, therefore, bond the rail joint in such a mechanical manner as to maintain perfect electrical contact, and with sufficient metal to restore at the joint nearly the full conductivity as of the rail itself, and, at the same time, to give the existing joint plates their present freedom of motion. It has been found that a system of track with faulty rail bonds will give a shock to animals and, possibly, to human beings, should the same be brought into actual contact in such a manner as to complete through them the broken circuit.



IRON WATER PIPE ONE YEAR OLD.

quantity of current above what should be the normal supply, thus augmenting the heating effect in the armatures and fields, the efficiency of the motors being reduced in corresponding ratio.

A further examination into other features of construction requires some consideration of the bonding of rail joints. The existing methods of utilizing railroad tracks for conducting large

It will be readily understood how difficult it is to maintain proper inspection of the electric bonding where the bonds are covered up by the street pavement. Under such conditions the ground circuit and the bonding escape inspection until excessive coal consumption, loss of current and other troubles force themselves upon the attention of the street railway manage-

ment. Observation proves that a faulty rail bond will show its location in winter by heating, due to high resistance, and if snow be present on the ground around the joints the snow is partially melted, thus indicating the location of the fault. Let us turn our attention for a few moments to the question of the conductivity

FROM A TELEPHONE CABLE COVERING IN A CONDUIT.

of the rails. For the purpose of comparison, we will assume that iron has six times the resistance of copper, the actual proportion being 1 to 5.63. Upon this basis the following table has been prepared:

Notation.	Fifty-six Pound Rail. One Rail.	Fifty-six Pound Rail. Single Track of Two Rails.	Seventy Pound Rail. One Rail.	Seventy Pound Rail. Single Track of Two Rails.
Area in square inches	5.4874	10.9748	6.8593	13.7186
Equal in area to circle whose diam. is in in.	2.642	3.735	2.95	5.90
Equivalent in circle mils. to	6,980,000	13,960,000	8,702,500	17,405,000
Resistance per foot B. A units	.00000845	.00000422	.00000679	.00000330
Equivalent to copper resistance in cir. mils.	1,175,000	2,350,000	1,463,000	2,926,009
Equivalent to copper rod whose diam. is	1.13	1.533	1.21	1.71
Safe carrying capacity of iron reckoned at ⅓ that of copper in ampères	390	780	488	976

Prepared by G. F. Sandt, E. E.

NOTE.—In the above statement the areas of rails have been determined by the use of the planimeter. The ampère capacity of iron has been based upon the most reliable data obtainable.

The table further on, compiled from data furnished by Mr. A. E. Kennelly, gives the current strength that can be carried by iron wire, within doors, in still air, and without becoming unbearably warm to the hand; that is, not to exceed a temperature of 50° Centigrade:

B. & S. Gauge.	Ampères.	B. & S. Gauge.	Ampères.
10	16	1	58
9	19	1	67
8	21	00	77
7	25	000	90
6	28	0000	105
5	32	½″	117
4	37	¾″	203
3	43	1″	302
2	50		

These figures serve to show how utterly absurd it is to bond a track of seventy-pound T rails with iron rail bonds No. 4 or No. 0 in size, and to pretend to reinforce their conductivity with a No. 0 iron or even a No. 0 copper wire. It is like laying a twelve-inch water main and then putting a one-half inch pipe alongside to help it out. The No. 0 B. W. G. copper wire has a resistance of over twenty times the single track of fifty-six pound T rails per foot, and the No. 0 B. W. G. iron wire, over 112 times the resistance per foot of the same track. How, then, can either of these be of any adequate assistance for conducting current? The diagrams on the next page indicate the small value of a supplementary wire of either iron or copper when compared with the conductive capacity of a properly bonded single track of fifty-six pound rails. All the areas are in accurate proportion for comparison. Fig. 1 shows the area of a circle indicating the single track of fifty-six pound rails. Fig. 2 represents the iron reduced to resistance of copper. Fig. 3 shows the No. 1–0 supplementary copper wire, and

Fig. 4 the No. 1–0 supplementary iron wire reduced to resistance of copper.

The writer knows personally of several instances where the copper supplementary wire has absolutely disappeared. He believes that ninety-nine per cent. of the money expended for so-called supplementary wire is absolutely thrown away. The same money expended in other directions would give more adequate return. Does not this show conclusively that we should give our attention to the more perfect bonding of the rail joints, and also to apply track feeders in such a manner as to fully utilize the conductivity of the track and thereby make it fulfill the service of which it is capable when properly treated? We are in error when the track system is named as a return circuit. The track system of all electric railroads should really be the positive side or outgoing circuit. It will be readily understood that as the current travels from positive to negative any arc which occurs between the trolley wheel and the trolley wire will carry metal from the trolley wheel and deposit the same on the trolley wire. If the reverse method of connection is made, the trolley wire will lose the metal and deposit it on the trolley wheel, and in time the strength and conductivity of the wire must be seriously impaired, eventually resulting in breakages.

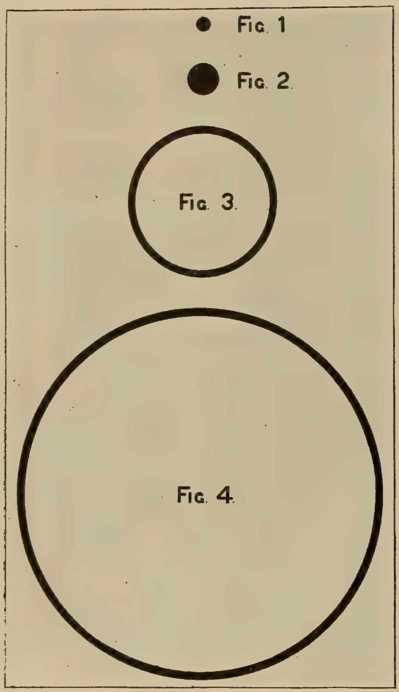
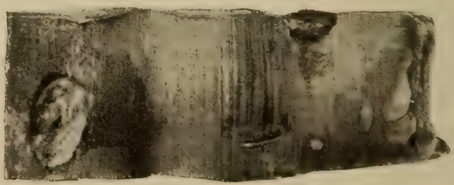


DIAGRAM SHOWING SMALL VALUE OF SUPPLEMENTARY WIRE.

It is also important that existing systems of operating electric railroads should be promptly taken in hand and the proper remedies intelligently applied. The three-wire system has been mentioned by some engineers as a possible solution. I will here diverge for a minute to state that a trial was made four years ago under favorable conditions—not to avoid electrolysis, but to save copper. We developed physical difficulties of operation which warned us to avoid the three-wire system in future electric railroad work. I believe I am safe in stating that ninety per cent. of the electric railroads have their systems so constructed as to largely restrict the conductivity of the rail circuit. A one-sided system is fundamentally wrong. The quantity of current to be controlled is so enormous that ordinary make-shift methods will not answer.

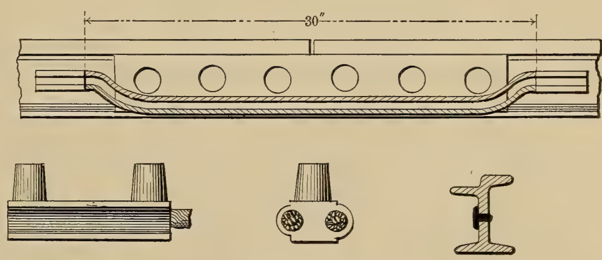
Having carefully analyzed the whole matter, I feel justified in recommending that we must adopt the complete metallic circuit as the standard for the best electric railroad practice. This can best be obtained by the following method: First. By so bonding the track as to render the rail joints of as low resistance as, and nearly equal con-



FROM A TELEPHONE CABLE COVERING IN A MANHOLE.

ductivity to, the rails, and to execute this work so as to maintain this improved condition. Second. The track system must be supplied with insulated feeders leading direct from the bus bars in the station to predetermined points of the track system, and thus offer a perfect low resistance path for this side of the electric circuit, the same as is obtained with the trolley line and the overhead system. All of these features and improved methods have been put in practice by the writer.

The only proper system is one that affords a well insulated and complete metallic circuit of low resistance, that will give an ample path for the complete unrestricted circulation of the entire current from pole to pole of the dynamo, thus offering no inducement for the current to follow such conductors as gas or water pipes, but, as it were, actually robbing the earth of any desire to carry the current. I am not recommending extravagant methods, but only such as are deemed essential for economy and of a practical nature for reducing expenses and augmenting dividends. The item of cost cannot properly be urged as an objection, because where the whole construction requires a large investment, every detail of the work should be so executed as to be permanent and enduring. If the details are carefully analyzed, it will be found that the cost of frequent reconstruction, maintenance and renewals of rail bonds and bare wire amount to an excessive rate of interest on original investment, and would soon pay the small additional cost to build a complete metallic circuit. The superior service obtained from a complete metallic system of low resistance with the proper application of insulated track feeders will, within a brief period, more than refund a reasonable interest on the investment through the saving of fuel alone, not counting other economies in renewals and maintenance. The track feeder system will be far less costly than the double trolley system.



VAIL'S RAIL BOND.

Whether track feeders should be laid underground or erected overhead is a question largely controlled by local conditions and capital available. I express a preference for underground work as being more permanent and subject to the least cost for repairs. The original construction is certainly more costly for underground. The actual cost of copper is the same in either. The necessity of constant repairs, under existing methods, and the damage to water and gas pipes by electrolytic action, simply proves that it is but a question of time as to how long before electric railroad companies will be forced to adopt the complete metallic circuit. Where experience and practical knowledge is applied, the cost will not be excessive. It is not difficult to arrive at an exact method of doing the work and an accurate estimate of its cost.

The writer has observed on some roads that large quantities of copper for return circuits have been placed at great expense, apparently without a proper conception of how to obtain the best results. Frequently a far less amount of copper, judiciously applied for improved distribution by the feeder system, would give superior equalization of pressure at reduced cost. If for the movement of cars singly or in quantities at a high rate of speed the electric current is to be distributed uniformly over an electric railroad system, the subject must be handled with as much scientific accuracy as is always used for a perfect system of incandescent lighting, in order to obtain equal distribution

and free flow of current in both sides of the system.

The writer has fully and completely provided for all contingencies in the following manner: First. By a careful study of the conditions under which a system will be operated. These important points being ascertained with reasonable accuracy, the requisite supply and distribution of current for the service is determined, and the system of conductors arranged to meet the requirements. For the proper supply of electric current, the important underlying principles of the feeder system must be thoroughly understood. Second. The conductivity and current-carrying capacity of the track system is calculated, and a system of insulated track feeders is provided, leading from the switchboard in station and connecting at predetermined points, and with a calculated fall of potential. Each feeder must be determined for its maximum current requirements at a stated drop in potential. The actual work required of the feeder and number of track feeders necessary is determined upon such factors as the cars in service, their weight, speed and headway, the position of the power station and the geographical lay of the railroad system, the weight of rails, and whether double or single track, and the amount of load concentrated on sections of track between feeder junctions. The carrying capacity or conductivity of the sum total of all the feeders of the system will be found to give complete and ample circuit for the free flow of the entire current required, and to take care of extra heavy traffic and blockades at any point. The parallel track main is only applied in sections of systems extending over very large territories and long distances. The conductivity of the rails is calculated with as much care as the overhead system, and when the track needs reinforcing, the purpose is accomplished by laying a thoroughly insulated main line (not a bare line) and making frequent sub-feeder connections bonded to the track. If used at all, this main will be of large size.

Such a system accurately worked out, will show by actual test with instruments on the cars a surprising equality of electro-motive force throughout a large territory. A very careful test has been made with instruments on moving cars, throughout a system covering forty miles of streets, with double tracks, equal to eighty miles single track. The readings showed—maximum volts, 512; minimum volts, 420; average of electro-motive force over entire system, 460 volts, the electro-motive force in station, at bus bars, being 520 volts. The feeders were calculated for a ten per cent. drop. The actual average drop from dynamo to motor does not exceed twelve per cent. This will be found to result in reduced fuel consumption, better working of the motors, a most satisfactory reduction in repair accounts, and an improved general economy of the entire system. In the system of distribution secured by the above method, the use of ground plates, rods or other insufficient methods is needless; the current travels only over the paths provided for it, and electrolysis of gas and water mains is entirely obviated.

Since presenting the above facts to the National Electric Light Association various comments have been made in electrical journals, requiring, apparently, additional explanations of some of the details. One journal says: "Indeed, after showing the absurdity of using copper conductors of ordinary size alongside the rails, it was rather surprising to see the author lay so much emphasis on the importance of track feeders." Now I have stated in the latter portion of the paper that for the proper supply of electric current, the underlying principle of the feeder system must be thoroughly understood. I said this advisedly, knowing full well that the principles of the feeder system are not well understood. It is only by many years of practical work that one becomes cognizant of the flexibility and advantages of the feeder system. Space will not permit a detailed explanation, but possibly the interested reader may study out for himself the advantage of the feeder system from the following

statement: The feeder is determined for a specified current delivery under a calculated fall of potential, and is connected to the main, or consumption circuit at such a predetermined point as will be benefited by an increased supply of current and a raised electro-motive force. The feeder, when properly applied, practically places a portion of the station capacity, less the loss on the feeder, directly on the main, or consumption circuit at the point of the feeder junction. Therefore, we may look upon a system of distribution properly supplied with feeders as if actual dynamos were pumping current into the system at all the points of feeder junctions, and maintaining an equalization of potential throughout the system.

By the intelligent use of feeders, the actual dynamo capacity of the station is sub-divided and applied (minus the determined drop) at the requisite points of the distributing system. The principal involved is that the current will return or be pumped from the rails direct to the dynamo through the low resistance insulated track feeders in preference to any passage through the moist earth or other circuits of higher resistance.

Another journal apparently assumed that I endorse the proper bonding of the rail joints as a complete cure for electrolytic action. Such an assumption is incorrect; the proper rail bonding is only a partial remedy. From a study of the table of track resistance, it will be readily perceived that conditions arise where car service and length of track cause a natural fall of potential which must be revived by the current supplied through the track feeders. The combination of perfect rail bonding and insulated track feeders therefore compose for the track side of the system the complete and metallic circuit; either alone is deficient for the purpose, except for light car service on short sections of track. Again, the same journal stated: "The addition of track feeders would be of great assistance, but it would be a mistake, we think, to use insulated wire for this purpose. The reason for this is that the insulation will in no way add to their conductivity,

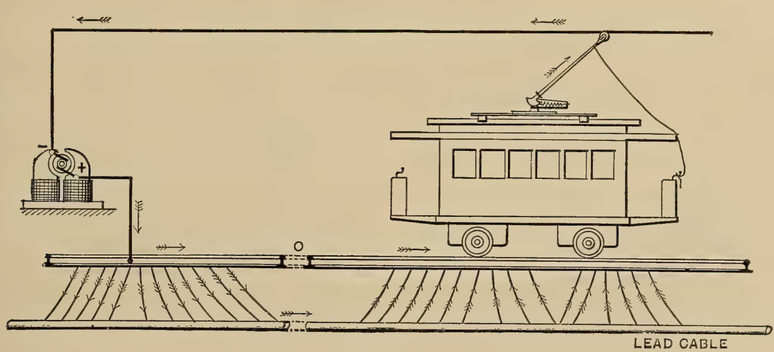


FIG. 5.

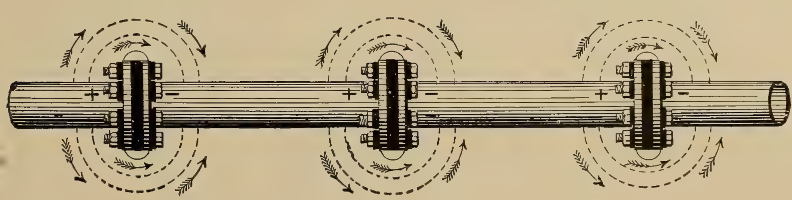


FIG. 6.

and the leakage through the ground will be as great with the insulated feeders placed on poles as were the feeders of bare copper buried directly in the ground. In fact, the latter disposition of the feeders would doubless have some advantages in that, in being uninsulated, the resistance between them and the track would be considerably less than if they relied wholly upon the track connections. It must be remembered also that track feeders alone have been tried and found wanting in at least one case where they were somewhat fully tried, probably partly for this reason and partly for the reason that insufficient copper was used." The writer of the above will undoubtedly change his opinion if he will read with care my statements describing the fate of the bare supplementary wires that have been buried in the earth. These disappear absolutely in a brief time. The same fate would overtake the bare feeder wire. An engineer might as well lay a water pipe full of holes as to bury an electric feeder without proper insulation. The most of the current would be lost from the bare feeder before it reached the consumption circuit.

Instances of an equally imperfect grasping of the idea of the "complete metallic circuit" might be quoted from other journals. I am not speaking from a theoretical point of view but of actual results obtained and electrolysis entirely prevented when I say that my system of complete metallic circuits will cure the troubles from electrolysis.

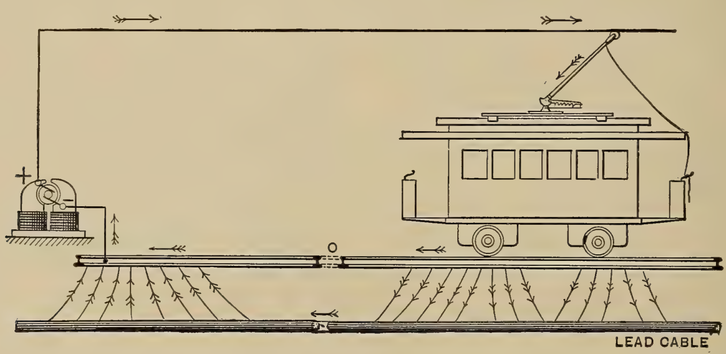


FIG. 7.

The recent report of the Board of Commissioners of Electrical Subways of the city of Brooklyn, N. Y., contains valuable data and evidence not heretofore produced, and from it many of the illustrations of corroded pipes and cable coverings accompanying this paper have been reproduced.

Before leaving the subject it is interesting to call attention to a paper devoted to it, recently read before the American Institute of Electrical Engineers by Mr. I. H. Farnham, and in which some valuable information is given. A great deal of credit is due to him for the many careful experiments which he made. Of the collection of illustrations accompanying the paper, several are here reproduced together with what the author says :

"Early in the summer of 1891, some lead-covered telephone cable removed from wooden ducts in Boston, showed some very marked yet local spots of corrosion. The cause of the corrosion was generally attributed to acetic acid contained in the wooden conduit, which had, years before, caused corrosion on a few cables in certain sections of the city. In the case just mentioned, the corrosion was so severe, and located in spots only, that it led me to attribute the cause to electrolytic action from the railway currents.

"Fig. 5 shows the passage of current from the dynamo to the rails, and the passage of a portion of the current from the rails to the cable within the neutral or zero line, and from cables to

rails outside of this zero line. The danger of electrolysis is only where the current is leaving the cable or pipe through the moist earth ; hence, the dangerous district was at this time outside of the zero, or neutral line, as shown. Several conferences were held for the purpose of suggesting and discussing means for preventing the destruction of the cables, at which the officers and experts of both the railway and telephone companies were present.

"First : It was proposed to remove all cables from the wet bottom and sides of the so-called manholes. It was found very difficult to place and retain cables free from the wet sides, and even could this have been accomplished, the action at the mouth of the ducts, and within them, would still have continued. They were, however, all removed from the bottom of the manholes.

"Second : It was suggested that the cables might be connected to ground plates in the manholes, and so transfer the electrolytic action to these plates, and thus save the cables. This experiment was tried on an extended scale, but though many ground plates having a surface of several square feet each, were connected with the cables over a large portion of the city, it was found that voltmeter readings taken between the cables and a point on the earth a short distance removed from the ground plate in any manhole, gave nearly the same pressure as before the ground plates were connected. In some cases, the voltage between the cables and the earth was reduced 25 per cent ; in many others, no noticeable reduction was made. The ground plates were constructed from pieces of old lead cable, 6 to 10 feet in length and embedded in the wet earth at the bottom of the manholes. It was evident from this test, that ordinary ground plates would not prove of material advantage for protecting the cables.

"Third : Insulating the cables and pipes from the earth was proposed. As some of the worst cases of corrosion of cables by electrolysis occurred where they were painted with asphalt, taped, painted again, and finally covered again with a heavy braiding also saturated with asphalt, it was apparent that to insulate cables sufficiently to protect them would be difficult and expensive, if indeed practically possible.

"Fourth : Breaking the metallic continuity of the cable sheath and pipes was proposed. From the fact that severe action is frequently found in comparatively isolated spots, where cables and pipes cross each other or pass near or across the rails, it follows that any system of breaking the metallic continuity, would have to be studied with reference to the entire complicated system of pipes, cables and rails ramifying through the streets of a city. There would also be a difference of potential between the several sections of cable or pipe, severed metallically, tending to cause electrolysis at one end

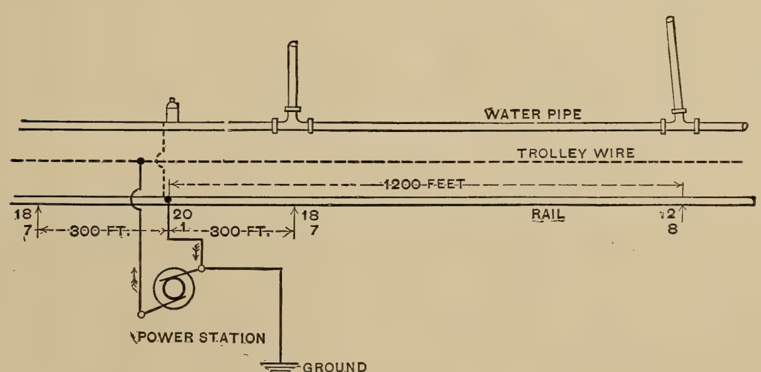


FIG. 8.

of each section, as illustrated in Fig. 6. In case of water pipes, treated in this manner, the action might be expected on the interior as well as on the exterior. There appears to be some evidence of such an action as this in gas and water pipes where the electrical continuity is partially broken by leaded joints.

"Fifth: My assistant, Mr. Towne, suggested that the railway current might be so frequently alternated, as possibly to prevent serious action on the pipes and cables. The theory was, that before the oxygen gas, liberated by the current, should have time to attack the metal, the reversal of the current would disperse it. A careful experiment was conducted, extending over a period of ten days, employing a pressure of current of from three to seven volts, and alternating its direction at regular periods of one minute, by specially devised apparatus. No material change had taken place in either plate during this period of time. We then considered the practicability of reversing the railway current frequently. It seemed possible to reverse it once each twenty-four hours, at a given time in the night when the load is comparatively light. To do this in a large system involving several power stations would require either a loss of current for a few minutes in order to guard against one station reversing before some other had opened or reversed its current, or would require some electrical system connecting the several stations together and operating the reversing apparatus simultaneously. We concluded it would be very difficult, if indeed at all practicable, to reverse such heavy currents during regular traffic. We then renewed the reversing experiment, giving twenty-four-hour periods between each alternation, but found at the end of two weeks, to our sorrow, that the plates subjected to the action of the current were seriously electrolyzed. It seemed useless to pursue this line of work further at that time. Fig. 7 is a typical representation of the current flowing through trolley, car, rails, and cables at this time. It will be readily understood that with the conditions as illustrated in this figure, the electrolytic action will be confined to the territory comparatively near the power stations where the current is leaving the cables to reach the negative or rail side of the dynamo.

"The engineer of the Water Board at Rochester, N. Y., suggested to me, a short time ago, while looking into the question of electrolytic action upon the pipes in that city, that possibly there might be sufficient resistance in the joints of the water mains to cause an action upon the lead ring which forms the connection between sections of pipe. He stated that not unfrequently there is found a film of moisture between the pipe and this lead ring, and as the pipes are coated with a preparation of tar or asphalt on both the inner and outer surfaces before they are laid, there might be a poor electrical connection. Without having made any inquiries or tests upon this point, it seems to me probable that the careful calking which is given these lead rings, would form in some portion of each joint a good electrical connection; that is, one of very low resistance. Recent measurements however, made in Boston, and others made in Albany, during the latter part of March, this year, convince me that there is a very appreciable resistance in such joints.

"Fig. 8 will illustrate the conditions at Albany. We found the negative side of the dynamo to be connected with the rails, and with ground plates in old wells; no connection had been made with water or other pipes. Directly in front of the power station the voltmeter indicated a pressure of 20 volts between the water pipe (an 8-inch cast-iron pipe) and the rail, the pipe being positive. A reading, taken about 300 feet in either direction, up or down the street, indicated about 18 volts. At a point 1200 feet north, the reading was lowered to 12 volts. We then connected the rail side of the dynamo to the street hydrant and took new readings, finding 1 volt at the station, 7 volts at 300 feet distant, the same south, and 8 volts at a point 1200 feet

north. These measurements, with similar indications in Boston, show plainly that there is a very appreciable resistance in the water main joints. At the same time the measurements give fair evidence that the difference of voltage between any two sections of water pipe is very small."

STEAM BOILER INSURANCE.

By W. H. Wakeman.

WHEN the writer was a small boy he heard some one speak of getting his life insured, and if it were possible to do this we wondered why it was that everybody did not take out a policy at once. This thought was due to a mistaken idea as to the meaning of the term "life insurance," for we thought that if a man had his life insured he would never die. In due course of time we learned that it was no guarantee of long life at all, but meant only that when a person, whose life was insured, died, his or her heirs would receive a certain sum of money. This made the matter appear in an entirely different light and we were not so enthusiastic as before ; but when we became old enough to fully understand the matter we saw that it had its advantages, and at the present time we heartily believe in life insurance.

We also believe in steam boiler insurance. In some respects they are alike. If a man wants to have his life insured, he makes application to some company who are engaged in that business, and is sent to the physician whose duty it is to examine applicants. The physician orders the candidate to do certain things, in order that he may know whether it is safe to issue a policy to him or not. He thumps and pounds him in different places, asks him to take long breaths, measures the expansion of his chest, listens for any sound that would indicate weakness of the vital organs and makes his report accordingly. If it is favorable, the policy is issued, and generally no further attention is paid to the policyholder, except to see that his premiums are promptly paid, and, when he dies, to pay the insurance money according to agreement.

When a man wants to get a steam boiler insured, he also makes application for a policy to a company in that line of business. The company sends one of its inspectors to examine the boiler and ascertain if it is a good risk. This inspector strips the boiler and examines every part of it. He thumps and hammers it with his small steel hammer, and listens carefully for any sound that will inform him whether any of its vital parts are weak or decayed ; he sounds every sheet, head and brace, and taps every rivet that he can reach to see if it is loose. If he finds any defect, he orders it made good before the policy can be issued. If he is in doubt about any part that he cannot reach with his hammer, he may apply the hydrostatic test to satisfy himself that it is more than strong enough to withstand any ordinary steam pressure. Up to this point boiler insurance is very much like life insurance. But the boiler is not allowed to go without further notice when the insurance premium is paid over. The insurance company make periodical inspections of it, and note how it is cared for and managed. If any defects are found, they must be remedied at once or else the policy will be canceled. They make a point of claiming to prevent boiler explosions to a large extent ; hence, if a boiler does explode while under their care, it not only costs them a good sum of money, but it injures their reputation, and thus proves a damage in two ways. Therefore, they

have two objects in view when they strive to prevent boiler explosions, each one of which is enough to cause them to exercise care in placing and continuing a policy in force. It is this prevention which manufacturers and steam users prize and pay for fully as much as the idea of getting their money when an explosion does take place.

If a man dies, no one thinks of blaming the company that issued a policy of insurance on his life, for the way in which he died ; but if a boiler explodes, the insurance company that was interested in it is looked on with suspicion at once. True, some of the defects in boilers are very difficult to discover, especially where the latter are nearly full of tubes below the water line, but every boiler that does explode, shows that by a careful and thorough examination of every part of it, the defect might have been discovered in time to prevent the catastrophe. It is quite possible that some of these defects might have been brought into existence between two inspections, but it is also true that inspectors are not afforded all of the chance that they should have to examine every part of the structure. Even if it does become necessary to remove some bricks for this purpose, it should be cheerfully done, as the result of it may mean much to all parties concerned. It cannot be denied that risks are sometimes taken in cases which are not wholly satisfactory, for competition in this line of business has its effects just as it has in other lines, and a company will take some risk rather than let business go to a competitor.

In a certain case, well known to the writer, the inspector wished to have some bricks removed from the top of a boiler so that it could be determined whether the iron had been weakened by external corrosion or not. The case was stated to the proprietor in a respectful manner, but he flew into a rage at once, and told the inspector that if he could not insure the boiler just as it stood, he might "get out" without delay. Both inspector and engineer might have taken the advice so vigorously given, but as neither of them knew that the plates were corroded on the outside, and as both of them knew that they were perfectly sound so far as could be judged from the inside, they went quietly about their business. The engineer removed the bricks in question, affording access to the top of the boiler and put them back himself. He lost no time, however, in looking up another situation. In this case there was no real danger, but no one could say positively that none existed ; still if danger had been imminent, the action of the proprietor would have been the same, for he knew nothing of the condition of the boiler.

Proprietor, inspector and engineer should all work together in striving to get at the true state of affairs, for all are interested. There was a time when boilers could be insured with some companies, just as houses are, but experience has been a wise teacher, and few are now insured without careful inspection. There is no doubt that the periodical visits of the inspector act as a check on the careless and incompetent engineer. Unfortunately, however, they do not always change him into a competent and reliable person. Cases are known where the gauge cocks were carefully cleaned out just before each one of these visits were made, and after the inspector had satisfied himself that they were in good order, they were not disturbed until it was nearly time for another visit

It is claimed by some that the practice of having boilers inspected and insured, has resulted in lowering the wages of engineers, for, with the inspector making visits every three months, a cheaper man will answer every purpose in the estimation of some steam users. This, however, is probably not true to any extent, for while it may be spoken of as an excuse for lowering wages, it is apt to be done only by those who intend to reduce wages any way, and think this to be a good excuse to give for "penny wise, pound foolish" policy. It is a notable fact that where the highest salaries are paid to engineers, and where the best

service is rendered in return, the boilers are generally insured. A sensible manager will always hire a good engineer and pay him fair wages, and a foolish one will hire the one that will work for the smallest amount of money. The boiler insurance problem has little effect in either case under any conditions, and usually none at all.

Steam users who have never had their boilers insured and who contemplate trying the experiment, are naturally anxious to know whether the insurance company will require them to employ a more competent man to run their boilers or not. To this it may be replied that if a man will keep sober and make every reasonable effort to give satisfaction with his work, the insurance company will offer no objection to him. Their leniency in this respect is, in fact, sometimes to be wondered at. Cases are known to the writer where it would have been perfectly justifiable for the company to cancel the policy unless the boiler attendant was removed, because he persisted in practices that were positively dangerous. Very little trouble, however, was encountered in these instances, for the insurance company would send their inspectors around to visit such a place at frequent intervals, ostensibly for some other purpose, but in reality to observe the proceedings of the suspicious man, and to remonstrate with him, and impart information as to better methods to pursue, the object being to remove the objectionable practices without depriving the perpetrator of his situation. Inspectors, while going from place to place, gain much information concerning the behavior of boilers under different conditions, and the result of experiments made to determine various problems of interest to engineers and firemen, and their information is always at the disposal of men who operate plants where the insurance company is interested, since obviously it is to their interest to have men who thoroughly understand their business in charge of boilers on which they carry risks.

The publication of data regarding boiler explosions in a systematic manner, as practiced by some of the insurance companies, is to be commended, but it seems as if the publication of lists of so-called defects were at times misleading, or at least of little value. Take, for illustration, a report that during a single month 149 broken and loose braces and stays were discovered, and that of this number thirty cases were dangerous. The writer is of the opinion that if 149 braces were loose or broken, then 149 were dangerous, and if 149 were not dangerous then they could not be either loose or broken. All braces are supposed to be in a boiler for a certain purpose, and how can they act in the way that was intended, if they are either loose or broken? We are told in another case, that 291 plates were found to be fractured, but only 44 were dangerous. If a boiler plate is really fractured, is it not dangerous? If it is not dangerous, then why is it reported? Of defective riveting 1288 cases were found, but only 66 were reported as dangerous; 382 defective water gauges were found, with only 84 reported as dangerous. The writer has always supposed that if a water gauge was not defective it would show a true water level. It cannot be imagined how a water gauge can ever be defective, and still not be in a dangerous condition. If 59 safety valves were found to be of defective construction, it seems strange that but 19 of them were dangerous; 476 pressure gauges were defective, out of which 42 were dangerous. This latter is easily understood, for while a gauge which indicates more pressure than really exists in the boiler is defective, it cannot be said to be dangerous.

While writing, one of several points worth noting in connection with boiler inspection suggests itself. An inspector, for example, comes to a plant, examines a battery of boilers, and tells the engineer what defects he finds, makes suggestions as to what might be done for the improvement of the plant, orders some changes and takes his departure, leaving with the engineer no written report of what he finds and wants. The engineer proceeds to make such changes and renewals as he understands will be

satisfactory to the inspector, the boilers are put together, filled with water, fired up and the plant is started. About three weeks afterward, a written report is sent to the office telling what the inspection revealed, and what repairs are needed. When this is referred to the engineer, he discovers that there apparently was not a perfect understanding between the inspector and himself, the report calling for things that have not been done, although there was a desire on the part of the engineer to do all that was required. Such possibilities should be and can be guarded against at once. All that the inspector has to do is to leave a written report with the engineer at the time that the inspection is made. There can then be no chance for misunderstandings.

A certain inspector came to examine some boilers at a plant where his company was interested, but found that the engineer was not quite ready for him, not yet having washed out the boilers. He started to do this at once, but the inspector objected as he claimed that if a stream of water was turned into them then they would be wet, and it would be unpleasant to work in them. The engineer, therefore, allowed them to remain as they were, but was much chagrined two or three weeks later when the report came, stating that the boilers were in good condition, except that they needed a good washing out. Ever since then no inspector goes into those boilers until they are washed out, without regard to polite requests made to let them remain as they are.

Concerning the recommendation of certain methods for future use in caring for boilers, the inspector should be discreet and careful, for no universal rule will answer the purpose. This is due not only to the fact that different waters are used for making steam in different localities, but also because the inspector cannot know all of the conditions found in every day practice. Usually he does not recommend any patent preparation for the prevention and removal of scale, etc., but favors the use of soda ash, crude petroleum, or something similar. But suppose that an engineer has used soda ash, for example, and found it unsatisfactory for some reason or other. He succeeds in discontinuing its use by showing his employers that he has good reasons for rejecting it, and secures something else that does good work and is not objectionable. The inspector comes in due time, looks the boiler over, and goes away. When the report of the inspector is received, the engineer is disgusted to find that soda ash is recommended to prevent scale. Of course the engineer has to go all over the matter again with his employers, and of course he gains his point, and the soda ash is not used; still it has been the cause of much talk and some unpleasantness, both of which were unnecessary. It is better for the inspector to ask what has been used in the past, and if the article is not positively objectionable to him, let him recommend a continuance of it, or let both engineer and inspector agree on something to be recommended, and thus prevent unnecessary conflict.

THE OVERHEAD TROLLEY SYSTEM.

By O. M. Rau.

THE much-abused, though silently welcomed, electric trolley street railroad system has received considerable attention from inventors and street railway managers within the last few years. Through their combined efforts a point of perfection has been attained, where, it is safe to say, no radical improvement will follow, and a system constructed on the standard of to-day will not be much outclassed by future construction. Not only is there little room for the perfection of an overhead trolley line, but the minds of the inventors are now taken up by the underground and storage battery systems, and the drift in improvements for electric street railways will be in these directions.

Discussing the subject recently before the Wisconsin Electric Club, the author took the stand that the maximum success which an overhead trolley system can attain has been reached, and capitalists need no longer wait in deciding to use this system, expecting to see it brought to a higher point of perfection.

The improvements from the first overhead line to the present form of construction have been astonishing. Yet to the untrained eye it appears the same eye-sore as the first one put up, and it must be admitted that very little has been done to improve its general appearance. This could be accomplished with little expense, by artistic poles and neat wiring, which would do a great deal toward its approval by the public. The main efforts in improvements have been to make it safe and reliable. The system of three years ago is like a flimsy spider web compared to the heavy structure of to-day. Instead of a No. 4 or 6 trolley wire a No. 0 is used ; instead of poles made of gas pipes, a special drawn steel or lattice pole is used, and instead of making the material as light as possible, it is made strong, without reference to weight.

The system of poles for a trolley road is still much discussed, and between side and centre pole construction there is so little preference that it is impossible to adopt any one as a standard. Local conditions must determine which to use. The side pole has in its favor the small cost of maintenance, but the greater first cost has prevented its use on suburban lines and the opposition of property owners to having poles in front of their houses, as well as the hindrance to the fire department, have proven serious objections to its use in the business portions of cities, and the centre pole has been adopted wherever the streets are wide enough to allow poles to be placed between the tracks. The main advantage of the side pole system, as stated before, is the limited cost of repairs which is mostly due to the flexibility of the system. The span wire suspension forms no rigid construction, and there is a certain amount of slack which will give under the pressure of the trolley wheel, thus avoiding the sudden blow to the trolley clamp, keeping the wheel in more perfect contact with the wire, and reducing the liability of the wheel jumping. The life of a trolley wheel is considerably increased by these advantages, as the tension on the trolley base spring need not be so heavy, and the friction is reduced both on bearing and periphery of wheel. These advantages lead to the adoption of the side pole system where a large number of cars are operated, which would warrant the extra expense of this construction.

The preference of city authorities, as well as by property owners, is for centre pole construction in the business portion

of cities. A thoroughly constructed centre pole system should not be any more expensive to maintain, with the exception of wear on the trolley wheels, than the side pole system, and if the poles are of neat design and well maintained, their presence will not affect the appearance of a street, and certainly will prevent ambitious drivers from occupying the whole roadway. The danger of the poles being close to the cars is very slight, and, up to the present time, no serious accident has been attributed to this cause.

The cars must be provided with gates on the inside platform, whether side or centre pole construction is adopted, as the danger from jumping in front of a car running in the opposite direction is equally as great as coming in collision with the poles. By having these gates well secured, any accident from this source is avoided; the danger from bridges, where the truss construction comes very close to the cars, is far more serious than from the centre poles.

For first-class construction, as well as embodying neat appearance, the lattice or built-up iron pole has proved most substantial. This pole is very strong, and, at the same time, has enough elasticity to prevent its bending from any sudden blow or strain. The poles well set in concrete, about six feet in the ground, will keep a trolley line from getting a staggering appearance, and there is nothing that improves the looks of a pole line more than systematic construction. For side poles, the lattice type is much used, but a heavy tubular form is also convenient. The setting of these poles should be similar to that of centre poles, but should have a rake in the opposite direction to the strain and should be fitted with an insulated pole top.

The span wire is a very important part of this plan of construction, and should be insulated from the ground and securely fastened with provisions for taking up slack. These requirements are easily met by mounting the pole with a hardwood top, usually of maple, well painted, through which a hole is bored for an eyebolt with a thread, so that by tightening a nut it will draw the eyebolt through the pole top and tighten the span wire, which should be of ¼ inch galvanized steel cable.

The trolley wire bells or insulators, of which there are about as many styles

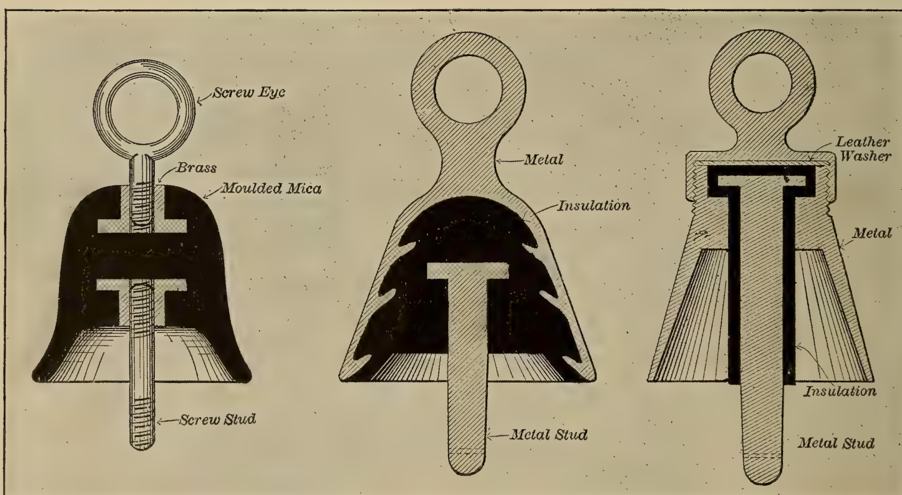


FIG. 1. SECTIONS OF TROLLEY INSULATOR BELLS.

as there are men selling them, form the principal item of expense in the maintenance of an overhead system, and this should receive the most careful study before a specific bell is adopted. Of the numerous forms, some of which are herewith illustrated, the only satisfactory one, from a financial point of view, is the metal-covered form shown at the right in Fig. 1. It should have means of fastening to the span wire or centre pole cast on the outside shell. This will do away with additional parts as well as screws or eyebolts. The illustration represents the three stages of improvement in trolley insulator bells. At the left is the molded insulation type, with threads on the upper and lower ends into which the eye bolt or stud is screwed ; the middle one is the metal-covered form with a taper stud molded into insulation which wedges between mechanical clamps to hold the wire ; the third has a metal shell with detachable insulation, and is the latest improved form.

For span wire work, the standard form, conventionally called a straight line hanger, is the most suitable and quickest to hang. The centre pole has given occasion for various patented forms to be placed on the market, such as placing springs between the bell and pole arm, and other devices to form a flexible connection between the pole and hanger, to do away with the rigid fastenings when simply bolted to the pole ; but the numerous forms tried by the author not only proved too expensive, but of very little value in aiding the flexibility of the line.

A fastening very much employed for centre poles is the swivel joint which allows the bell to swing forward or back, as the trolley wire may have occasion to draw it. This has given rise to a large number of trolley wire breaks, as the clamp holding its position at right angles to the bell will draw the trolley wire out of a straight line, and when the bells hang at an angle the end of the clamp is presented to the approaching trolley, which, in a very short time, will have nicked the wire so that it will break. This plan of fastening was made necessary from the large number of clamp studs or screw eyes which would break when the bell was bolted to the pole rigidly. The improvement made in overhead parts has changed this, as the screw eyes and studs are either done away with entirely or increased in size, so that they will stand any reasonable strain. When the bell is fastened as a rigid fixture to the pole and the trolley wire held firmly in it, each pole will receive its own share of the strain from the wire and need only take care of the span between it and the next pole. In this manner the bells will remain at right angles to the trolley wire and the clip or clamp will always remain in a straight line. The clamp or clip is perhaps the most troublesome to decide on, although a selection between a mechanical clamp or a soldered clip is usually in favor of the former. A soldered clip, although giving the neatest appearance as well as the smoothest surface to the trolley wheel, is expensive to put up and interferes considerably in repair work, which unless done with the utmost care, will be a continual source of trouble. In fact, any device which requires soldering is not to be recommended on a trolley system. The average line man is not careful enough with this work, and will invariably overheat his solder, which will soften or anneal the wire more in this spot than elsewhere, resulting, when under strain, in its drawing out at this point, making it thinner and ultimately breaking. This is most noticeable in the soldered sleeve, and over 20 per cent. of trolley wire breaks can be traced to the heating of the wires during soldering.

A mechanical clamp, to be substantial, should have as few parts as possible, be free from screws or nuts, and hold the wire firmly without interfering with the trolley wheel. There are numerous patented devices to attain these effects, but nine-tenths of them have too many parts, are too weak, or cost too much. A very important feature which has been overlooked in most mechanical clamps is the corrosion of the threads on the studs or screws which form the

means of holding the clamp to the wire, and, in numerous cases, I have seen where the clamp had to be cut to pieces in order to get it off the trolley wire. The stud in the bell should be extra heavy, not less than 5/8 inch, as this is very likely to break. For centre poles this stuff must be especially strong, as the strain on this part of the hanger is very great, and the number of line patrol calls is greatly governed by their strength. It is, perhaps, interesting to see what a difference this simple little stud makes to the patrol department of an extensive electric railway system. From the record sheets of a line having about eighty miles of road and about 4,000 bells on centre poles, a total of 3,700 calls were recorded for the year 1893-4. Of these 3,230 were to replace bells on which either the screw eye on top or the screw stud on the bottom of the bell had broken. These were 7-16 inch in diameter. From this it is apparent that almost every bell on the system was replaced during a period of one year. With proper construction on a centre pole system there should not be more than one hundred calls per one thousand bells per year, or a depreciation on the system of about ten per cent., not including value of bells taken down, which can be repaired or used again.

The exposed position of the hangers has favored the use of brass for the metal used in the material, but this simply increases the expense, and is of no special benefit, as the strength of malleable iron is far superior to that of the cheap grade of brass generally used, while the corrosion is insignificant on these castings.

The sizes of trolley wire used in the evolution of electric street railways has now arrived at a standard, and it is peculiar to note that the first road operated used the present standard size of wire, which is No. 0 hard drawn copper. The experiment of using silicon bronze of small gauge has proven a very costly line to maintain, besides increasing the wear on the trolley wheels. The wear on a trolley wire on straight lines is imperceptible and a line should last at least ten years without re-wiring, and with good road beds and rigid inspection of trolleys the breaks should not exceed one per mile of double track road per year.

An important, but not much used, plan for trolley wire systems is the auxiliary main distributing system, Fig. 2. This auxiliary main of No. 0 insulated copper wire is usually run along the top or side of centre poles, and at intervals of 600 feet is connected by means of No. 4 flexible wires, termed sub-feeds, to the

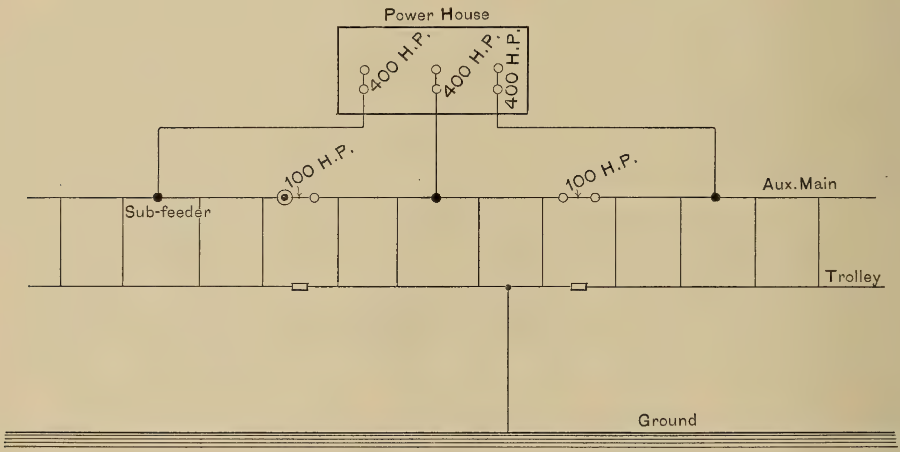


FIG. 2.—THE AUXILIARY DISTRIBUTING SYSTEM.

trolley wire. The connection is made by a sub-feed clamp. This is the ordinary clamp provided with a lug and set-screw to firmly clasp the sub-feed wire, making a connection through the clamp with the trolley wire. The advantages of an auxiliary main are very numerous. By its means a more equal distribution of power is obtained, the connection at switches and crossings need not be relied on to carry the current, and the drop on long lines is overcome, which otherwise would have to be wired with a larger size trolley wire. It is especially useful in carrying the current over crossings of other lines or where the trolley has to be insulated through a circuit breaker. The expense of adding this auxiliary to a trolley line is very small and should not be omitted in an extensive system. The distribution of the current to an electric railway has not received the attention that it should, and a great many roads simply take the ends of the trolley wire and connect them to the station bus bar.

A thought of equalizing the potential is never entertained; yet every one knows that a motor built for 500 volts cannot operate with efficiency on 350 volts, but this is very commonly the case near the ends of a line, and in many instances this drop can be avoided to some extent without the addition of copper by a proper plan of distribution. In a system covering an extensive area, where feeders to different sections are used, a very interesting study can be made of feeding sections to obtain the best results in accordance with the number of cars and other local conditions. This I have carried out in a very extensive plan on the system of Milwaukee. There are twenty-one feeders to distribute the current over a radius of three miles from the power house and supplying current for forty miles of double track.

The original plan of feeder sections was probably laid out theoretically according to the size of the feeders and the distance they had to feed. By taking potential readings during the operation of the road, I found in some instances a drop of 25 per cent., while the calculated drop should not exceed ten per cent.; and on another feeder but two or three per cent. where ten per cent. was allowable. By changing the sections so as to obtain the largest area of copper, or make a loop circuit for one feeder section, and by arranging the sections according to the profile of the road, this excessive difference of drop was considerably equalized, although there was still some difference in the potential of different sections which could be easily noticed when passing a circuit breaker from one section to the other. The advantage of having

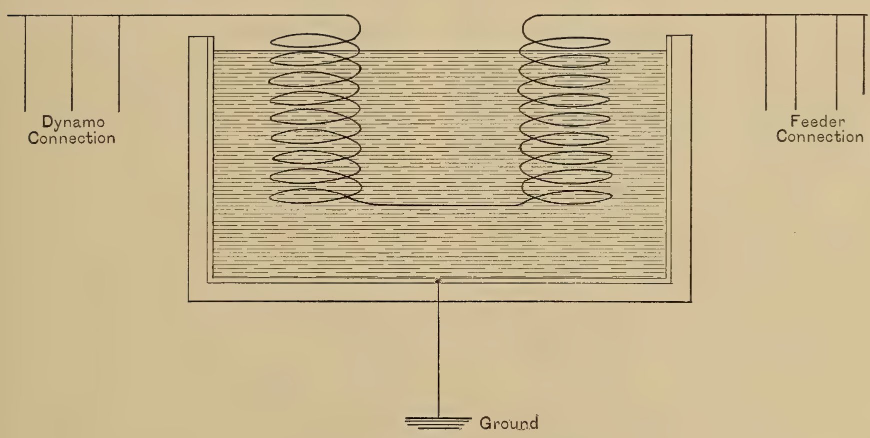


FIG. 3.—A TANK LIGHTNING ARRESTER.

the line in sections is very important; a trolley wire breaking or other accident happening to any particular section will delay only that part of the system. Yet the only way to equalize the pressure over the entire system is to have all the feeders connected together as one large web work, similar to an illuminating distributing system where the mains would resemble the trolley wire. To obtain this advantage I placed a fuse box between each section, with a fuse of one-fourth the carrying capacity of the main fuse on the feeder in the station. The fuse was fully capable of carrying all the current necessary to equalize the pressure between the adjoining section and still was so light as to blow if the plug or fuse in the station was out. In this manner a wire down, or other ground, would blow the station fuse first, this supplying most of the current feeding the ground. After this was blown, the light fuse of the section would blow immediately, leaving the grounded section dead. The repairs to the system would be made without greatly delaying the operation of the road. The potential over the entire system is equal and would be perfectly feasible to supply current for lights and motors for commercial use from the trolley wire system.

Another important part of an overhead system is the apparatus for protection from lightning. In plants where an extensive overhead feeder system is in use this is a troublesome enemy, and the safest trap for it is a tank arrester at the station, Fig. 3. This was perfected by A. Wurts, and consists of a coil of heavy wire placed in a metal lined tank filled with water and connected with a perfect ground. The total current generated is passed through this coil before it is distributed through the feeders. Any lightning discharge which follows the wire is obliged to pass through this coil, and, as lightning will be opposed by induction in attempting to follow around the coil, it will prefer to take the path through the water to the ground. This arrester has proved very efficient, and, although a slight loss is continually going on through the water to the ground, this is not objected to, as the tank need not be filled with water except during storms. For trolley line protection a number of lightning arresters have been devised, although but few embody the requirements for an outdoor arrester. To protect a large system against lightning requires about one arrester for every mile of trolley wire, and, considering the distance covered by a trolley system, an inspection at intervals of this apparatus is out of question. Thus, a lightning arrester suitable for line work must be non-arcing, have no movable parts about it, or coils which can burn out, and must be enclosed in a weather-proof box, with suitable outlets for connecting wires, which should be large, and perfect connections should be made to the trolley wire and track.

LEADING AMERICAN ENGINEERS.—PROF. EDWIN J. HOUSTON.

PROF. EDWIN J. HOUSTON, whose name has, indeed, become a familiar one to the engineering fraternity, and especially to the electrical section of it, comes of an old and distinguished Southern family, having been born at Alexandria, Va., in 1844. That branch to which he belonged removed to Philadelphia before the war, and there young Houston was sent to the public schools and in due time reached the Central

High School of Philadelphia, from which he graduated in 1862.

Almost immediately after completing his studies at this school, he was appointed a prefect at Girard College, where for some little time he also taught surveying and navigation. In 1866 he was called to take a position in the Central High School, having been unanimously named professor of Civil Engineering, at that time an important department. Shortly afterward he was appointed to the chair of Physics and Physical Geography, which he filled for twenty-six years with great credit and honor. In 1872 he spent some time at the Heidelberg University on studies and investigations connected with his own special field of work.

In 1875, he became associated with Professor Elihu Thomson, then an assistant professor at the Central High School, and formerly one of Professor Houston's first pupils in physics, and together they set to work in spare time to apply their knowledge of electrical science to the production of arc-lighting, succeeding, ultimately, in achieving both fame and fortune. In the words of Professor Houston : "We wanted to make a dynamo with such automatic attachments that the average stupid man might successfully operate it." They set up a workshop in the little room in the basement of the school, which is now occupied by lunch venders, and for nearly two years they worked, often till the early hours of the morning, developing their machine. Fully realizing the importance of their work the young firm secured a patent for each device as it was constructed, and the entire legal work was done by their own unaided efforts, for they were too poor to have an attorney. When the dynamo was finally completed, a company was formed, with the assistance of George S. Garrett, a wealthy gentleman of West Philadelphia, and a shop opened to build others.

People were slow to recognize the valuable points of the new system, but an arc light put on exhibition in a local cracker bakery, attracted considerable attention, and orders began to slowly come in. The first contract of any magnitude which the firm undertook was the lighting of John G. Gardiner's Continental Brewery at Philadelphia. The dynamo for this order was built by Mr. Wm. Harrison, in his machine shop at Eighteenth and Barker streets, Philadelphia. A fire broke out in the brewery shortly afterward, and the firemen were astounded at the failure of their streams to extinguish the lights. Finally, they turned the united force of all the engines on a single light, but in the midst of the deluge the light remained undimmed, and weird stories of the light that never failed were circulated among the engine houses of the city. Shortly after this, in 1879, a contract was received for lighting the Reading coal wharves so that unloading might be carried on after dark, and the Thomson-Houston Electric Company were successfully embarked on a career which is yet too recent to have faded from memory.

Professor Thomson moved to the Lynn factory of the company in Massachusetts to personally watch its growth and development, but Professor Houston, while retaining an interest and share in the company, remained at the High School, not wishing to tear himself away from the boys whose instruction had become the charm of his life. Meanwhile he banished leisure with literary, scientific and public duty, and a long list of books, in great part devoted to electrical subjects, has been one of the outgrowths of his industry.

In 1884 he was appointed by the United States Government as a member of a commission to hold an electrical exhibition in Philadelphia, conducted by the Franklin Institute, and was appointed chief electrician of the International Electrical Exhibition held at that time, the success of which was acknowledged to be largely owing to his untiring efforts.

So highly are Professor Houston's abilities recognized in the province of educational development that Professor

Eliot, of Harvard University, appointed him, in 1892, a member of a conference of ten to consider the best methods of teaching geography. Although Professor Houston submitted a minority report of one, that report was practically the one which was adopted.

In 1893, Professor Houston was appointed one of the three presiding officers of the Chicago International Electrical Congress. His writings and his speech betoken great versatility, and it is difficult to say whether he holds a higher reputation for scientific knowledge, educational ability, administrative talent or business capacity. More recently he resigned his position in the Central High School and associated himself with Mr. A. E. Kennelly, under the firm name of Houston & Kenneły, to devote his entire time to electrical expert work and consulting electrical engineering, accompanied by scientific research, all of which subjects have increasingly demanded his attention in late years.

He is an honorary member of the American Electro Therapeutical Association, a member of the Franklin Institute of Pennsylvania, of the Société Internationale des Électriciens, of the Academy of Natural Sciences of Philadelphia, president of the American Institute of Electrical Engineers, president of the Athletic Club of the Schuylkill Navy in Philadelphia, a member of the American Philosophical Association, and has an honorary degree of Ph.D. from Princeton University. He is also a director or manager of several important corporations, and his bachelor home at Philadelphia, presided over by his sisters, is a charming resort of genial hospitality and scientific enthusiasm.

Current Topics.

In the light of the economies that have been effected in the running of boilers and engines, bringing the cost of power down to figures which only a few years ago would have been considered chimerical, the report on the cost of electric station operation, recently made to the National Electric Light Association by one of its committees, supplies rather interesting and suggestive reading. It would seem that the inquiries of the committee were extended over a large number of stations, and it is safe to presume, therefore, that

the figures obtained represent average results, and pretty fairly indicate what it costs for coal to generate a certain amount of electrical energy in current practice. The best result, according to the published data, was 208 watts, and the poorest, 30 watts per pound of coal per hour, with an average of about 92 watts,—a very low figure indeed, when it is borne in mind that this means a consumption of about seven pounds of coal per horse-power per hour. Evidently, there is opportunity for a good deal of profitable missionary work among electric light station managers. With seven pounds of coal necessary to generate an electrical horse-power for one hour, it is not strange that we should hear of electric light investments yielding poor returns. A little more liberal employment of engineering talent would help to tell a different story.

WITH all the promise that has been given of the coming reign of the electric storage battery for the propulsion of vehicles of various kinds, the growth of steam carriages still flourishes. Particularly true would this seem to be in France where, of late, such carriages appear to have been a favorite hobby with inventors, and a number of designs have followed one another in short order, indicative, in a measure, ot the faith which is being put in the existence there of a demand for apparatus of this character. The chief feature of interest in all these carriages, of course, centres in the power equipment, or more correctly speaking, in the means adopted for keeping down the service weight of this equipment to the lowest notch without seriously restricting the range of action, and it is to the boiler of each outfit therefore that we should probably look more particularly for novelty of design. This, in one of the latest forms of French steam carriage, is found in the adoption of a vertical, tubular generator fitted with a central fuel reservoir, much after the manner of the familiar magazine stove, permitting of running for a certain length of time without the necessity of attending to the fire. The chimney flue descends toward the bottom of the carriage, with a rear discharge, and into it also issues the exhaust steam from the motor. The boiler is arranged at the front of the carriage, together with a box for the storage of coke, which is the fuel used.

FRENCH STEAM CARRIAGE.

At the rear there are seats for four persons, including the motorman, and underneath is a water tank. The motor, which is a small, compound, high-speed engine rated at six horse-power, weighs about 290 pounds ; the boiler weighs, when empty, 350 pounds, and the total weight of the carriage, in service trim, is given as a little over 3500 pounds. The maximum regular working speed is placed at about nine miles an hour, and the frame carrying the boiler and engine is completely independent of that forming the seat, so that none of the jarring of the engine is felt by the passengers. What the practical ad-

vantages of a carriage of this kind are, however, is not quite clear, and there would seem to be little reason for building one, unless, indeed, its purpose be to demonstrate the possibilities of a steam engine and boiler combination as a car fixture for the satisfactory handling of city street traffic on a much larger scale. But, aside from these considerations, the vehicle is interesting as one of several current illustrations of foreign inventive activity.

THE principle of the baffle plate, whose value is pretty well established as a means of more fully utilizing the available heat of combustion gases in furnace flues before being allowed to escape into the chimney, has been recently applied, apparently to good advantage, in the making of a tube for feed-water heaters. It is known as the Row tube, and its peculiarity is very well illustrated in the accompanying sketch. Originally circular in section, the tube is indented, as shown, making it more or less irregular in outline, the surface not being increased, but its efficiency as a transmitter of heat being very greatly augmented owing to the actions of the indentations causing turbulence in the stream of water or steam passing through it. It has been claimed, in fact, as the result of experiment, that the efficiency per square foot of surface and per degree of difference of temperature is practically doubled, as compared with plain tubes, so that the weight and dimensions of a heater in which the new tube is used may be considerably reduced. A heater equipped with this style of tube is now being put on the market in England.

THE ROW TUBE.

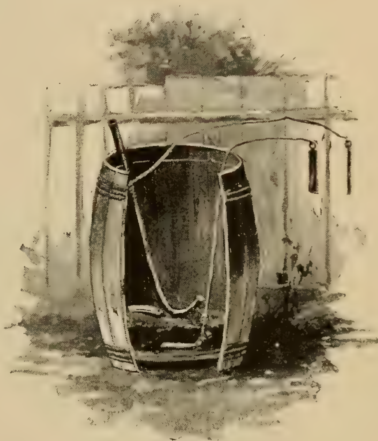
THE idea of making a chain without welding up link by link in the customary way has, of late years, been followed with a good deal of interest, and several patented processes have made their appearances, designed to avoid the objections which can be made, with more or less reason, to the common, welded product. One of the most interesting of these is the scheme of substantially rolling a chain from a solid bar of metal of cruciform section, the rolls being practically a series of dies, each of which punches pieces out of the bar so that, ultimately, perfect chain links are produced, being still connected, however, to one another at the points where the inner side of the bow of one link crosses that of the adjoining ones. In this shape the bar represents a rigid chain, but, on being passed through still another machine, it comes out with loosely connected links, though somewhat roughly formed. A series of finishing operations follow, ending with a perfect chain. The process almost throughout is a cold one so that there is no danger of burning the metal. Heat is applied only near the end of the operations when the chain is annealed in an oven. The length of the bars used, of course, limits the length of one continuous section of chain, and the several sections necessary to form a complete chain of any desired length are coupled together by special links. The process is now in practical use in England and has been applied, with apparent success, to the making of chains in several currently-used sizes.

MAKING A WELDLESS CHAIN.

THE discussion of electrolytic destruction of underground gas and water pipes, lead coverings of telephone cables, and the like by what might very appropriately be termed runaway currents from electric street railroads, is now all the rage. Papers on the sub-

ject have been presented in numbers before the several electrical societies, and electrical journals everywhere have devoted column upon column to accounts of the damage that has been done, and of the ways and means that have been proposed and tried to avoid it. Despite all that has been said and written, however, interest in the matter has been by no means exhausted, and every new contribution to the literature of the subject forms profitable reading, adding its quota, big or little, to the startling array of evidence already adduced that something must be done, and that promptly, to check the active destroying agency now at work beneath the street surfaces, and in buildings along the lines of electric roads. Mr. J. H. Vail's paper, published in this issue, and detailing the importance of complete metallic circuits for such railroads, is a most valuable exposé of the subject, and will repay careful study. Each of the illustrations accompanying it tells a suggestive story of its own, and helps to portray in a more striking manner than can be attained by words alone the important character of the electrolysis evil. The extracts which he has made from Mr. I. H. Farnham's paper, presented a short time ago to the American Institute of Electrical Fngineers, add further weight to his own remarks, and help to round out a contribution in which every electrical engineer, every gas and water-works official, and all municipal authorities should feel vitally concerned.

An interesting experiment recorded by Mr. Farnham, though not incorporated in the extracts in question, is worth mentioning here, having been made by him with the view of proving the theory that the corrosion of underground pipes noted was really due to the action of electric currents. A barrel of earth was procured from an excavation in a street, a metal plate was placed beneath the earth in the barrel, and two short pieces of lead cable were placed side by side on top of the earth. The plate in the bottom of the barrel was then connected to the negative side of a storage battery giving four volts potential, and one piece of the cable lying on the earth was connected with the positive pole of the storage battery. The second piece of cable in the barrel was left without electrical connections. The earth was then saturated with water and the circuit was closed, allowing the current to pass from battery to cable, to earth, to plate, and to battery for seven consecutive days. The pieces of cable were then removed and the piece which had been connected with the battery was found badly pitted, closely resembling a corroded cable which had been dug up from one ot the streets. The second piece of cable showed no corrosion whatever, proving conclusively that the damage was caused by the current, and that the corrosion was not due to any acids or salts in the earth which had been considered likely destroying agents.



AN EXPERIMENT IN ELECTROLYSIS.

Aside from the corrosive effects of currents running along gas and water pipes, there is still another most important matter demanding attention, and that is the fire danger in buildings into which pipes carrying such currents enter. Mr. H. C. Cushing, Jr., one of the electrical inspectors for the Boston Board of Fire Underwriters, in writing recently, in The Electrical Engineer, ot unknown causes of fire, stated that in cellars and basements of many houses he had found quite a large difference of electrical pressure between two pipes entering within one foot of each other, and in one instance it was a very easy

matter to take a piece of hoop iron and draw an electric arc sufficient to ignite a piece of waste held near it, and by connecting these pipes with a piece of No. 18 copper wire, the current flowing through it was sufficient to heat it so that it was impossible to lay the hand upon it. In the basement of another building he found a man using twenty-five ampères at eight volts pressure, by simply twisting wires around two different water pipes which entered the building. Again, his attention was recently called to two pipes which were so close together that the vibration of an elevator engine caused them to knock together just sufficient to create an arc every time that a contact was made and broken. This had been going on so long that it had almost completely eaten through the gas pipe, and it is perfectly evident what would have taken place had this been allowed to go on unobserved. The gas would have been ignited as soon as the first small hole appeared, by the electric spark, and disastrous results would have undoubtedly followed. This difference of electrical pressure upon water and gas pipes is now so well known that in a number of cases in Boston and Cambridge the ordinary electric bell battery is entirely discarded, and the wires from the bells are connected directly to water pipes, the latter furnishing an inexhaustive supply of electricity at the proper pressure to run any number of bells or gas lighting apparatus, and also to do any quantity of mischief.

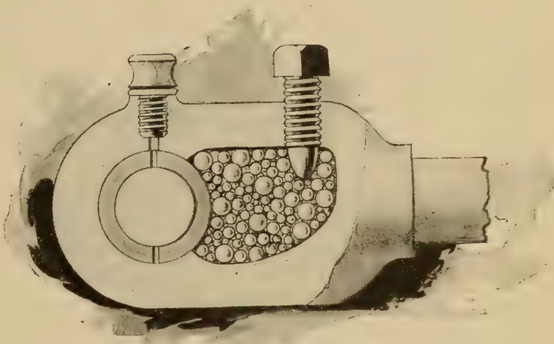
WITH all the refinements that have been made in fire extinguishing apparatus, the fact remains that the simple pail of water is, even at this day, one of the most efficient pieces of apparatus of this class that has yet been in use. Insurance statistics indeed show that more fires are put out by water pails than by all other appliances put together, the only point that can well be raised against them being that, while they are generally provided abundantly enough in places where they are likely to be of service, the water is very apt to be wanting. It is true also, in a measure, that, even if the pails were kept full, they are often borrowed for some purpose and not returned, so that when most needed they are unavailable. As a way out of this difficulty, it has been proposed to use pails with round or conical bottoms, which will not stand on a floor, and are not, therefore, likely to be taken off for some use for which they were not intended, but this form seriously diminishes the value of the pail as a fire extinguisher, since a man with two of them in his hand, arriving at the scene of action, cannot use either without setting the other on the floor and losing all its contents.

As an improvement on this, a superintendent in one of the large New England mills, who had found it difficult to keep the fire pails filled and in good order, some time ago adopted the following interesting expedient, of which we find an account in some scrap book data. The hooks carrying the pails were fitted up with pieces of spring steel strong enough to lift the pail when nearly empty, but not sufficiently so to lift a full pail. Just over each spring, in such a position as to be out of the way of the handle of the pail, was set a metal point, connected with a wire from an open-circuit battery. So long as the pails were full, their weight, when hung on their hooks, kept the springs down, but as soon as one was removed, or lost a considerable portion of its contents by evaporation, the spring on its hook would rise, come in contact with the metal point, thus close the battery circuit and ring a bell in the manager's office, at the same time showing on an annunciator where the trouble was. As the bell continued to ring until the weight of the delinquent pail was restored it was impossible to disregard the summons, and no more reason was found to complain of the condition of the fire-buckets.

THE obtaining of power from artesian wells delivering water under pres-

sure of some magnitude has, of late, commanded particular attention in the Western part of the United States, where, in several instances, wells of this kind furnish direct pressure systems of water-works for town supply, satisfying not only ordinary domestic needs, but those of the fire departments as well, without the use of the customary steam fire engines. In several cases, moreover, where the well pressure is considerably over 100 pounds per square inch, the water is used for driving electric light plants and flour mills through the intervention of water-wheels, showing in a striking way that what had at first been regarded as a decidedly visionary scheme has been worked out in a very practical manner. In England, too, the driving of water-wheels by artesian well supply is not unknown, and in at least one case an overshot wheel has been operated by the water from such a well for more than twenty years, driving a color grinding mill and other machinery. The subject calls to mind a similar use which had been proposed for natural gas in the early days of gas well development. The gas issued from many of the wells at pressures of from 60 to 80 pounds per square inch, and it was thought quite possible to use it, first, in the cylinders of engines as a motive power, and then to exhaust it into storage reservoirs from which it could be drawn afterward for heating. The gas in one of the well districts was actually used in this way, being put directly into engines, and for a number of years gave apparently quite satisfactory results. One drawback to the method, however, resulted from the fact that the gas, as it issued from the wells, carried with it more or less sand, which must have worked serious harm in the cylinders by cutting the walls and pistons. To what extent this trouble was actually encountered is not generally known, but it must have been quite sufficient to bring the practice into disrepute and to prompt its abandonment even without the gradual failing of the gas pressure as the draughts on the supply became more general.

An ingenious means for setting up the bearings of journals, such as crank-pins and others, ordinarily fitted with stub or strap ends, was devised a short time ago by Mr. C. W. Hunt, of the well-known Hunt Company of New York, and seems well worth illustrating. The little sketch which is given of it here excellently sets forth the principal features of the contrivance, and calls for very little more in the way of explanation. The journal is fitted with brasses or boxes held, in this case, in the end of a connecting rod, and adjacent to one of these boxes is a cavity filled with hardened steel balls. These are of various sizes, and a screw with a tapering point is provided which can be made to press upon them, causing them to



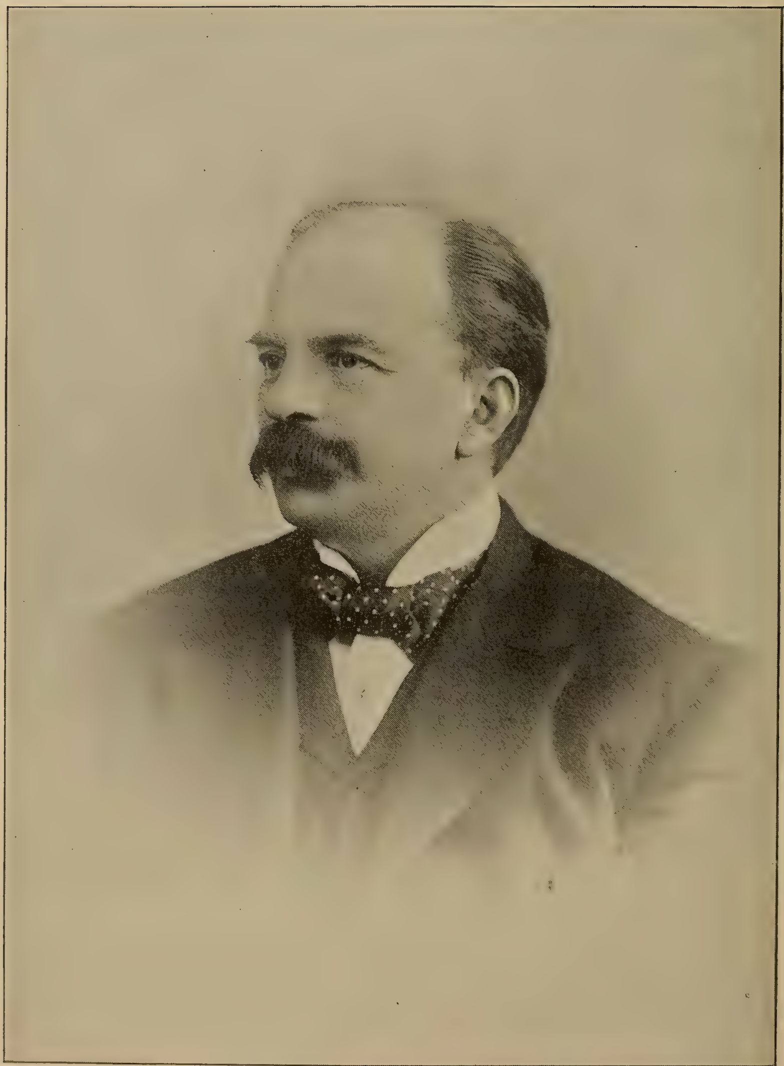
A NOVEL JOURNAL BEARING.

exert pressure among themselves and also upon the immediately adjoining box which is to be set up. If all the balls were of the same size, they would tend to pile regularly and become wedged in the cavity, but when they are of different sizes this tendency is avoided and the balls will slide and move one on the other, similar to the molecules of a liquid, and thus exert pressure equally in all directions. The device is, in fact, designed to secure substantially the conditions of a fluid and these seem to be well attained.

When the Tilghman sand blast process was first brought into public notice, more than twenty years ago, it created

quite a sensation. It has since then been introduced successfully into a number of industries, but, still, its use has been much less extensive than was predicted for it. An English firm is now advertising it with an illustration showing its use in cleaning castings. The original patents on the process having expired, the way would now seem clear for some enterprising one to manufacture apparatus for its convenient use for a variety of purposes, and to educate the public in its use. Information in regard to it, especially of a technical character, is difficult to obtain. Who knows, for instance, what pressure of air or of steam is required for the different uses to which it may be applied, what quality of sand or of other cutting material, what dimensions and arrangement of nozzles, sand receivers, air and sand tubes, etc., are necessary, how much air, sand, horse-power, etc., must be used for a given extent of work, say cleaning 100 square feet of iron castings?

WHEN two different liquids of different densities, but capable of mixing, are separated by a porous partition, a current sets in from each to the other. To these currents the names endosmose and exosmose have been respectively given, signifying impulse from within and impulse from without, and every student of natural philosophy is familiar with the phenomenon which they produce. The following story, however, which has just been started, affords a rather more entertaining illustration of it than is generally given in text-books on physics and, whether it be strictly true or not, it is worth repeating:—"We had been on a long cruise," so one of the officers of the United States steamer Albatross is made to say, "and were down near the tropics at Christmas time. Of course, we observed the day as well as was possible under the circumstances, and one of the features was a fine dinner. We had some champagne on board, but the weather was quite hot, and, having no ice, we were at a loss to find a way to cool the wine, which could not be endured as it was. During our cruise we had been making many deep-sea soundings, and it dawned upon us that by sinking the bottles down in the sea about a half-mile, we could find water as cold as ice. This was an inspiration, so we thought, and we immediately sent down a lot on a wire for refrigeration. At the proper time it was drawn up and placed on the table, and we found the bottles delightfully chilled. When the steward opened them, however, there was no 'pop' to the cork, and the wine looked flat and bad when served. What was our astonishment upon tasting it, to find that it was pure salt water! I thought, at first, that it was a bad practical joke, and ordered more wine sent down into the cold sea-water, but when it was opened, we were disgusted to again find only salt water instead of sparkling champagne. You are probably puzzled to find a solution to the matter. Well, it is very simple. At the depth to which we sank the wine, the pressure is enormous,—so great, in fact, that the salt water was forced into the bottles through the pores in the corks, and, being more dense than the wine, completely displaced it." The tale has a somewhat suspicious flavor, but is none the less interesting.



Yours faithfully
J. S. Jeans.

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VIRGIN REDWOOD.

THE REDWOODS OF CALIFORNIA.

By W. G. Bonner.

TO those unacquainted with the solemn grandeur of the redwood forest, the above title may have little attraction. But those who are familiar in any sense with the restful quiet, those who have stood in its cool shadows, or penetrated its depths and become acquainted with its distinctive features, will at least glance over these pages, if for no other purpose than to be reminded of the endless variety of surprises to which they have been treated—of the marvelous things they have seen in the vegetable world, and of the indescribable sense of littleness which they have experienced while standing in the presence of the giants of this primeval forest. To a certain degree, also, they will serve as vouchers, as the writer is well aware of the utter impossibility to make the uninitiated comprehend the most direct statement of fact with regard to the tremendous growth of the redwoods.

When one first enters the redwoods he is apt to be disappointed if he has heard much of their giant growth ;

What is here given has been, in part, reproduced from a pamphlet prepared by the author a number of years ago at the request of the California Redwood Company of San Francisco. While some changes have occurred in the redwood industry since that date, they have scarcely been sufficient to materially detract from the timeliness of what was then written, and the article, together with the illustrations, prepared from recent photographs, is therefore of current interest.—THE EDITOR.

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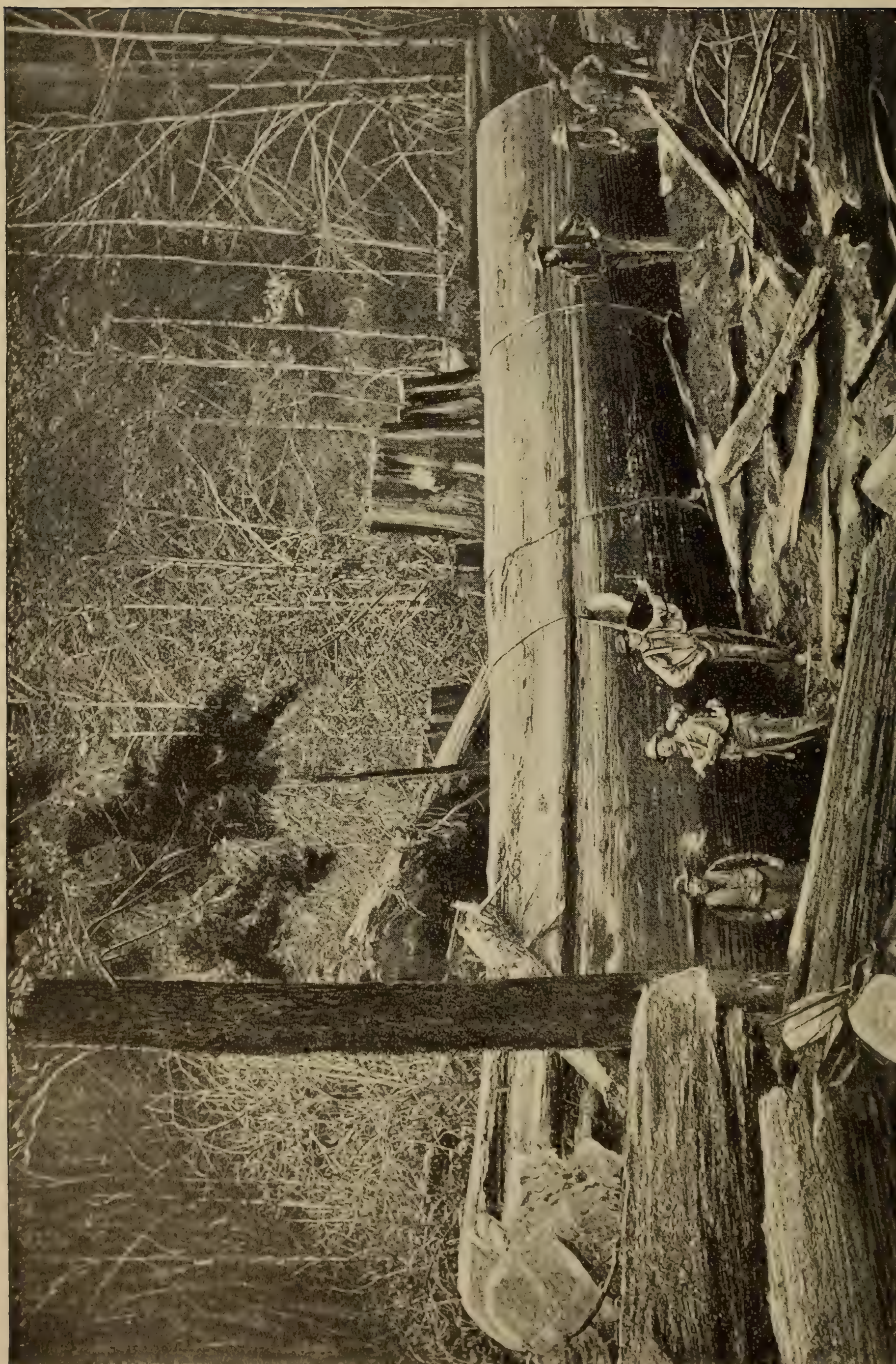
LUMBER SCHOONERS AT ARCATA.

if he has not, he is quite likely to feel no inspiration whatever, for in the outlying groves—the approaches to the main bodies of timber—the trees are usually of small proportions, comparatively speaking. This at least has been the result of the author's observations in many tramps by foot and saddle along the northern coast of California, the habitat of the redwood. But let the explorer penetrate this outer line of sentinels, or, better still, let him go frequently into the forest with gun or sketch-book or fishing-rod; let him search his way among the ferns, whose nodding heads he cannot reach, among the logs, over which he cannot see or even climb; let him witness the felling of even an ordinary redwood, with the attending crash and jar equaling the heaviest thunder tones, and he will presently discover that his whole being stands in awe of the ponderous yet majestic plant-life about him. He will discover that the softest of lights and shadows and the most exact outlines and proportions, the most delicate foliage, the fairest of wild flowers, of mosses, ferns and grasses, are everywhere in the shade of the great trees, making a picture which the most vivid imagination could not paint; and these, with a thousand other qualities of beauty, are so apparent as to impress not only the poetic or artistic mind, but the rough-handed woodsman, as he guides you through this veritable wilderness, is continually directing your attention to them. But these delicate artistic effects are apt—nay, are quite sure—to be lost upon him who first has the opportunity of seeing them. Even the perfect symmetry of the tree-trunks is lost upon him; their bulk alone interests him, and almost unconsciously he compares them with the forest trees of his Eastern home. There, he remembers, his shot-gun could bring down a lark or squirrel from the tallest tree; but he is satisfied that the best "Parker" could not reach the lowest limb of the tree he is just now inspecting. He remembers to have seen two, and sometimes three, saw-logs hauled on a truck or sleigh to the little mill on the river bank; but his imagination fails him when he tries to picture

the vehicle that must some day haul the logs from the trees about him. He measures the tree with his eye, noting the fact that it is as straight as an arrow, and without flaw or blemish as far as he can see, and timidly suggests that "it must be two hundred feet high!" "Yes," says the guide, "three hundred, or three hundred and fifty. You see these fellows are so thick that they don't look as tall as they really are." And then, perhaps, he will tell him of the man who actually built a house and barns and fenced his farm, with material all taken from one of these monstrous redwoods. Perhaps the wonder-stricken man will stretch out his arms full length and go round the tree, measuring the distance—six, seven, eight spans! Say forty-eight feet! In every direction, as far as he can see, and as far as his knowledge of the forest extends, are trunks of the same gigantic proportions—many, indeed, much greater in bulk. And then this new acquaintance of the "deep green wood" sits down to meditate.

How long have these giants been growing? How long have they stood watch by this western sea? How many hundreds of years—or thousands of years for aught he knows—have they guarded the mysteries of these mountains and valleys? How many ages have they nourished the brooks and rivers that flow beneath their shade, harboring the trout and salmon, and the thousand forms of aquatic life which infest their waters? What changes have been sung in their branches by the western winds? What stories of war, of life and death and regeneration, are wrapt up in their aged hearts? What, too, are the possibilities to man in this vast tract of incomparable woodland? The dreamiest of dreamers could not believe that nature had provided these stately groves for his idle pleasure alone, and the most unpractical man in the world will sometimes venture on a financial calculation.

ALONG THE EEL RIVER IN HUMBOLDT COUNTY.



A FALLEN GIANT.

Let the mind, then, take a practical turn, even in the dreamy noonday twilight that dwells in the heart of these forests.

Here, at a rough estimate, is an acre of hill land, or bottom land, or steep mountain land, as the case may be, containing perhaps forty stately redwoods, ranging from six to twelve feet and upward in diameter, and from two to three hundred feet in height, straight and thrifty to the very top. Here is one with long pendant limbs, extending well down toward the base, growing downward, and clinging apparently to the huge trunk. But they are exceedingly small in proportion to the tree, and seem to be more for ornamental than for useful purposes. That one just beyond is a clean shaft of seventy or eighty or perhaps one hundred feet, without limb or twig to break its outline. The "top" runs up a hundred and fifty, it may be two hundred feet above, with spreading or drooping boughs of a deep-green color. And here is one with still less "top"—not more than fifty feet—and perhaps two hundred feet of clear trunk! In every direction these giants are standing, and the eye goes from trunk to trunk, making its comparisons, or seeking one still larger that must be somewhere within the range of its vision. What a vast amount of lumber this acre of rough land represents! Shall I say one hundred thousand feet? It may be double that. But I will "guess it" at fifty thousand. And lumber is worth what? Twenty-five dollars. Twelve hundred and fifty dollars is the product of a single acre! And this is not a select acre, but one taken at random. Eastern lumbermen will probably marvel at these figures, but they are not extravagant. As a matter of fact trees are felled almost daily that will scale that amount per tree—yea, twice that amount!

To the redwood logger, trees less than four feet are of little account, and are rarely cut except for boomsticks or piles. But to return to our estimate. Besides the forty trees, more or less, there are upon this acre of land many more of smaller dimensions—mere saplings of two or three feet diameter—together with the seedlings, and spruces and firs and pines of various dimensions, which are also valuable as timber producers. All through the forest, too, are fallen trunks—chiefly redwood, for other kinds of timber soon decay—which would give perhaps a fair yield of lumber per acre, as compared with standing timber of other forests. How long these fallen trees have lain cannot be known—their lasting qualities vary somewhat; but as an evidence of their slow decay I may mention a group of redwoods, three in number, which grew beside the old trail from Freshwater creek to Elk river. The trees, of nearly equal size, were, when I saw them in 1879, about four feet in diameter, and about the same distance apart. They stood in a row, their roots clasping an old log, upon which the trees seemed to have been balanced with the nicest precision. This log was breast high, moss-covered and partly overgrown with ferns and bushes. An inch or more of its surface was decayed and yielded readily to my boot-heel, but underneath this covering the wood was as firm and fresh as if the tree had just fallen. How long it had resisted the process of decay was beyond my calculation; but it is well known that the redwood is not a tree of rapid growth, and this trio must have stood for a century at least, literally building upon the ruin of another. Similar evidences of durability are met with everywhere in the forest, and the huge windfalls are piled and cross-piled in such profusion as to turn the course of the most indomitable pedestrian. To the lumberman nothing could be more enticing than these dense redwood forests. I have often thought that the burly woodsman who attacks the diminutive pine of the East must experience a feeling of remorse, as would a strong man who made war upon a boy. But here there is something to compel his respect; he must feel that in grappling with these monsters he is doing the work of a Hercules.

There are numerous streams flowing through these forests and falling into the rivers or into Humboldt bay, or

directly into the ocean. These are the natural channels through which this world of wealth may be brought to market. They are small in the summer months, but their deep banks, and evidences of overflow everywhere apparent, testify to the winter torrents that sweep down their courses. Sitting in the still forest, with not even a bird-song to break the silence—for there is almost no bird-life in the redwoods, the bluejay and a tiny yellow warbler being the chief exceptions—one's imaginings know no bounds. At such times I have found myself speculating on the future wonder-land than these same redwoods, extending as they do for miles and miles along the mountain coast, reaching further toward heaven than any body of timber on earth, and waving their evergreen branches, like magic wands, over an everlasting life. I say everlasting, for the age of individual trees has been estimated at thousands of years, and the stumps of newly-felled trees refuse to die, but put out new shoots from top and side and go on with their business of growing. They are of very near kin to the famous "Big Trees" of California, differing from them mainly

A LOG TRAIN AT FRESHWATER.

commerce of these babbling brooks, or—in my mind—building tramways and railroads and steamboats to carry on the almost inexhaustible traffic that here awaits the busy hand of man. Yet quite as often have I thought how near akin to sacrilege it would be to lay the axe at the roots of these magnificent trees. For where else can the like be found? And if the greed of man is to lay hold of everything which possesses a money value, what will the end be? what shall be left to satisfy man's æsthetic nature? There is nothing more beautiful or more wonderful in all this

in being of greater numbers. They are a little less in size, it is true; but, while the big trees can boast of being nothing more than groves, the redwoods cover hundreds and hundreds of miles of territory. They are indeed a mighty race of giants, whose destruction must needs call forth the utmost energies of all the vandals of Christendom. And yet the work of destruction is going on, for the practical world has no eye for the beautiful side of the picture. It is still seeking the shortest route to Cathay, and everything is made to yield to that which will yield gold.

GOING TO THE MILLS.

And so I have wondered how it is that, with all the destructive propensities of the American people, and with the incessant and ever-growing demand for the very material which these forests afford in inexhaustible quantities, they have stood so long almost unmolested and so little known. From these "wonderings" I have come to inquire somewhat into the nature of these forests, their extent, and the quality and capabilities of the lumber, and the facilities with which men have worked, and are at work, to turn them into golden wealth. The results have astonished me beyond measure, and I have no doubt that many who fancy themselves fairly acquainted with the redwoods of California will find much food for thought in these few pages of information which I have collected.

The redwood is quite minutely described in "Forest Trees of California," a pamphlet issued in 1882 from the State Mining Bureau. "The wood is red, with a faint coppery or metallic irridescent gloss, the hues deepening to richer, darker shades with age. Choice curl-grained wood is very ornamental for cabinet finishing and similar work—takes a fine polish with a simple stain or varnish. Well-matured heart-wood of the base of these trees is so solid and heavy as to sink in water. These will last for ages under the most trying circumstances, like cedars and yews. Insects seem never to trouble any of it. The bark, reduced to bast, has been utilized for upholstering—an excellent material." The bark of the redwood has a soft fine fibre, and is of a spongy nature, the color being a rich reddish-brown, turning to a soft gray at exposed parts. It is usually deeply seamed, especially in old trees, and it is no uncommon thing to find it from twelve to eighteen inches in thickness.

"Redwoods abound chiefly, if not entirely, on sandstone soil, and are always confined to the fog limits of the coast—say fifteen to thirty miles inland, and probably never exceeding forty or fifty miles even in the most favorable parts of the low coast range, where the fog passes over low land or through open gaps. These mighty redwood wands possess a magic power over passing fogs, precipitating them in

A REDWOOD MILL.

showers of rain at their feet. For this mainly, among other good reasons, living springs of the purest water ever bubble and babble at their bidding.''

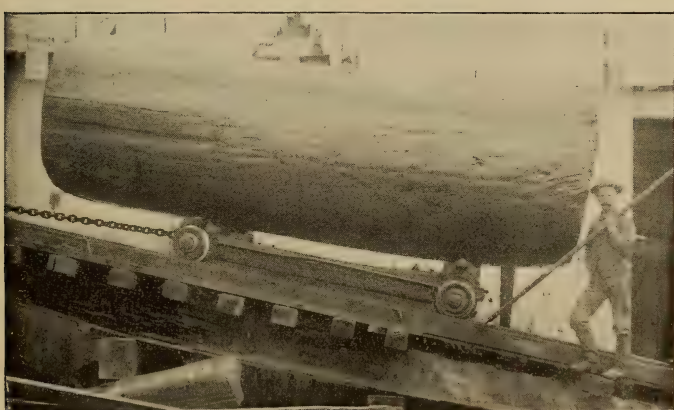
This is, perhaps, one of the secrets of the monstrous growth of these forests; for the dryest summer (and the summer months bring little or no rain in this region) has no appreciable effect upon the deep rich soil in the shade of their protecting arms. The temperature is even, and high enough to convert the forest into a vast hot-house, in which all plant-life flourishes. The various fruit-bearing bushes—the blackberry, salmonberry, thimbleberry, salalberry, and the like—attain remarkable proportions, while the sword and common ferns grow to monstrous size, often reaching a height of ten feet or more.

The redwoods extend along the northern coast of California from a little south of the Oregon boundary to the northern part of Monterey county, a distance of more than four hundred miles. The ''Forestry Bulletin'' (No. 13), published by the Government, gives a map showing the position of the belt, its dimensions and its variations as to density of growth and capabilities as to timber production. From this map and accompanying tables, it appears that the southern extremity of the belt is of no importance, and does not figure as a lumber-producing region. There is, however, a small body of timber in Santa Cruz county. With this exception there is no redwood for lumbering purposes south of Russian river, which empties into the Pacific perhaps one hundred miles north of San Francisco bay. The coast country then, from Russian river northward to the Oregon State line, covering a little more than three and one-half degrees of latitude, by from fifteen to fifty miles in breadth, according to different authorities, embraces all there is of the famous redwood timber, and to this tract the world will look for a considerable portion of

its building material in the near future. Indeed it is already drawing large quantities of the choicest lumber from this storehouse, not only for the building of houses, but for ship-building purposes, for car-finishing, furniture and cabinet ware, railroad ties, bridges, wine-vats, tubs, buckets, moldings, and the thousand-and-one uses to which wood is put. Shiploads go daily to Mexico, South America, the Sandwich Islands, China and Australia, while a vast market is being opened up for it in the Eastern States and in Europe. As to home consumption, it is sufficient to say that redwood has long been and is now the mainstay of the architect and builder of California, where scarcely a house can be found that is not built in whole or in part of this excellent material.

As already intimated, the extent and economic value of these forests, as well as their wonderful growth and indescribable beauties, were unknown except to a few practical, far-seeing men, until a comparatively recent date. The pioneer of California was a gold-hunter. He could not spare the time, nor had he the inclination, to investigate or experiment with things of this nature. But he had to build cabins and houses; and in many cases, when the gold fever had somewhat abated, he turned his attention to lumbering. A few saw that more gold was to be obtained through the useful industries of man than by the wild chase of the prospector. They saw in these forests unlimited wealth, and secured what they could of the prize. Naturally the attack was made at points easiest of access to San Francisco, and that portion of the belt was stripped off and is completely exhausted, the land being turned to grazing purposes with most satisfactory results. But this portion included only the lighter growth, the heart of the belt lying away to the north. Cautiously the few reached out into this domain of wealth, securing large tracts at Government prices, some for speculative, others for legitimate purposes. Gradually the business of lumbering was transferred from the exhausted regions around San Francisco bay to the dense forests of the north, until of late years all the redwood lumber supply has come from this direction. This change of base was followed by an increase of trade, which, in turn, induced greater developments, until the traffic in redwood lumber now

SPLASH !



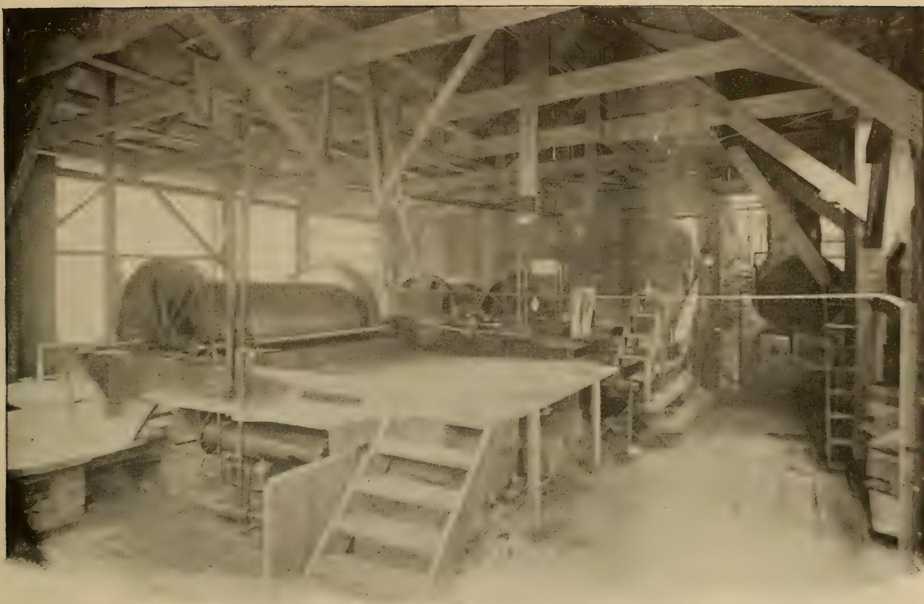
FROM THE POND TO THE MILL.

ranks among the first industries of the State.

The manufacture of redwood lumber has been going on in a quiet way for more than a quarter century; but men did not recognize its real value at first, and had but a vague idea of the vast supply in store. Besides, the demand heretofore has been easily met by mere trimmings, so to speak, from the edges of the forest. So the forest itself has remained—a legacy of untold value—for the use and profit of the present generation of hungry men. But its wealth is not limited to a gold value alone; for within its deep recesses the curious will find more to speculate on, and the lover of nature more to enjoy, than can be described in these pages. Rarely does one find a listener who will accept the dimensions of the sylvan monarchs he has met with. The stranger may allow a ten-foot tree, say once or twice in a day's tramp; but when you tell him of measuring any number of trees of forty or fifty feet in circumference you are wasting time, and possibly losing confidence in your own veracity, so decidedly is it questioned. Yet larger trees than these are met with everywhere in the forests of Humboldt county, and may be seen and measured by any one who will take the trouble. There is a "fallen monarch" in the Freshwater forest, some twelve miles from Eureka, whose throne was undermined by the little brook at its feet. It lies across the stream, making a bridge, along the entire length of which any stage coach might drive with ease and safety. Twelve feet above the surface roots its girth is sixty-three feet; and two hundred feet above the circumference is thirty-six feet. The length of the log is about three hundred feet, the top having been destroyed by the falling of the tree many years ago. There was a few years ago—I am told it has been washed away by winter freshets—a fallen redwood in the northern part of the county that was turned to good account by the packers of that section. The tree had fallen across a deep gulch near the turbulent Klamath river, along the trail to Orleans bar. It was utilized as a bridge, by means of which pack-trains and travelers regularly crossed the troublesome gulch for years.

A WOODS CREW AT DINNER.

Architects and builders, and wood-



A "BULL DONKEY" FOR CABLE LOGGING.

workers generally, have moved slowly in their experiments with redwood, as if they were not quite sure of their footing. But the ordeal has been passed, and it seems quite safe to say that no wood known to commerce is so well adapted to the general use of man. In its early history its use was carried no further than house-building in a cheap way. Little by little it made its way into favor, its numerous good qualities gaining for it a preference among those who had believed only in pine and other woods known in their Eastern homes. The shingles and shakes made from redwood began to attract attention by reason of their lasting qualities, and in time they came to be rated A 1, and were finally accepted as the very best roof covering to be had. In this country pine or other shingles are never met with, so completely does redwood answer all requirements. The manufacture of these shingles is carried on very extensively, almost every lumber mill having machinery for that purpose. Redwood was first introduced in the Eastern States in the shape of shingles. Now carloads and cargoes of them go regularly to New York and other Eastern markets, where they have met with much favor. From this has sprung up a lively demand for all descriptions of redwood lumber. A great drawback has been the excessive freight rates across the continent; but even with this disadvantage the trade is rapidly developing in that direction. Woodworkers in the East, as well as here, seem to have decided that redwood is good enough for all purposes, and it is being used wherever a light, yet strong and durable, wood is wanted. Its deep, rich color, and its being susceptible of the highest finish, make it especially desirable for inside housework, as well as for car trimmings and the like. Another important feature is the fact that when seasoned, redwood shrinks and swells less than any wood in use; in fact, it may be said not to shrink at all, if the experience of builders is worth anything. It may also be set down as a fact that insects and vermin will not abide within the walls of a redwood building. This, at least, is the testimony of householders. In Peru and Chili there are ants and other insects which destroy the native woods, as well as pine and other kinds of wood from this country, but red-

THE OLD WAY OF LOG HAULING.

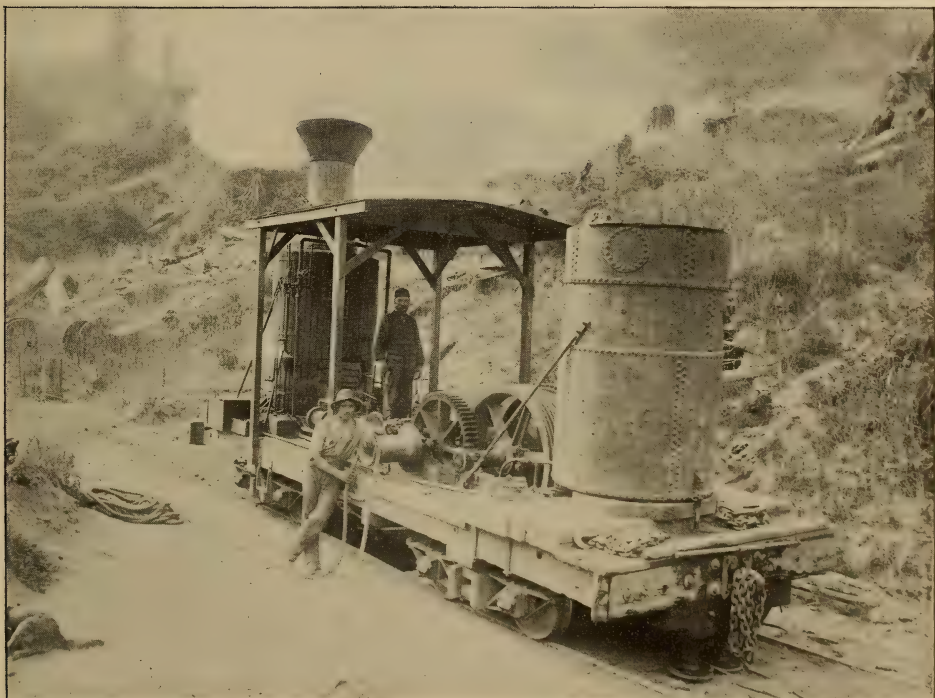
wood is never molested—a fact which is thoroughly appreciated in those countries, and which has helped to build up a large trade there. The wood has little or no pitch, and is not combustible like pine. Neither has it any odor.

The increasing demand for this lumber, and the belief among dealers and manufacturers that it is destined to replace other woods in the markets of the world because of its recognized superiority, has given a new impetus to the business. Large sums of money are being invested in it; mills are being established in all directions, as well in the forest as on the water front, and every branch of the industry is being improved by the adoption of new methods. The old ideas are passing away, giving place to new ones more in harmony with the spirit and enterprise of the time. Formerly the streams were used for bringing the logs to available tide-water points—they were the sole reliance of the lumberman. For this reason logging was carried on only along the streams and small rivers emptying into the bay. The timber was cut close along their banks in the summer months and rolled into their almost-dry beds, there to await the winter freshets. If the rains were light the streams failed to rise; and there was a log famine, with a consequent falling off in the lumber supply. The man at whose expense the logs were "put in" had to wait a year for his returns—in some cases two or three years; and even then many valuable logs were lost, becoming bedded in the sand or mud of the streams. Only the timber land along the streams had any particular value. This method had the advantage of being cheap, and is still in vogue in some cases where the waterway is particularly advantageous, or where lumbering is done in a small way and on small capital. But it is not equal to present demands, and has, as a rule, given place to better methods.

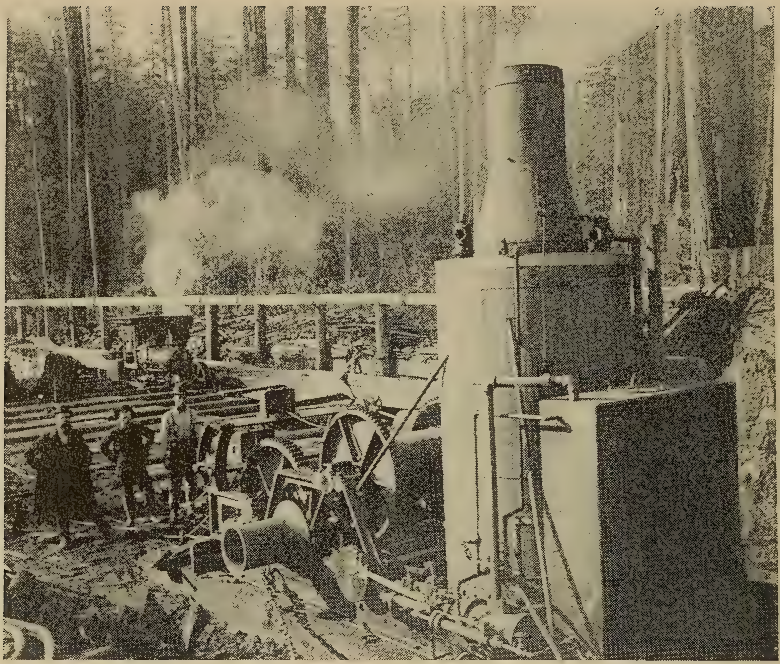
First came the tramway, built in the rudest but most substantial manner, its huge trucks propelled by ox-power. In the woods ox-teams of four, six or eight yokes were used in handling the great logs. The whole business, in fact, was conducted on the ox-power principle—

slow and cumbersome and unreliable. These tramways were built as auxiliaries to rather than improvements on the streams. They also made available certain portions of the timber which could not be reached by the old-time water process. These rude affairs have answered their purpose well, but they have had their day, being now found only where capital is lacking. They, like the uncertain streams, are too slow to satisfy the enterprising spirit of to-day. They have given place to the iron rail and the iron horse.

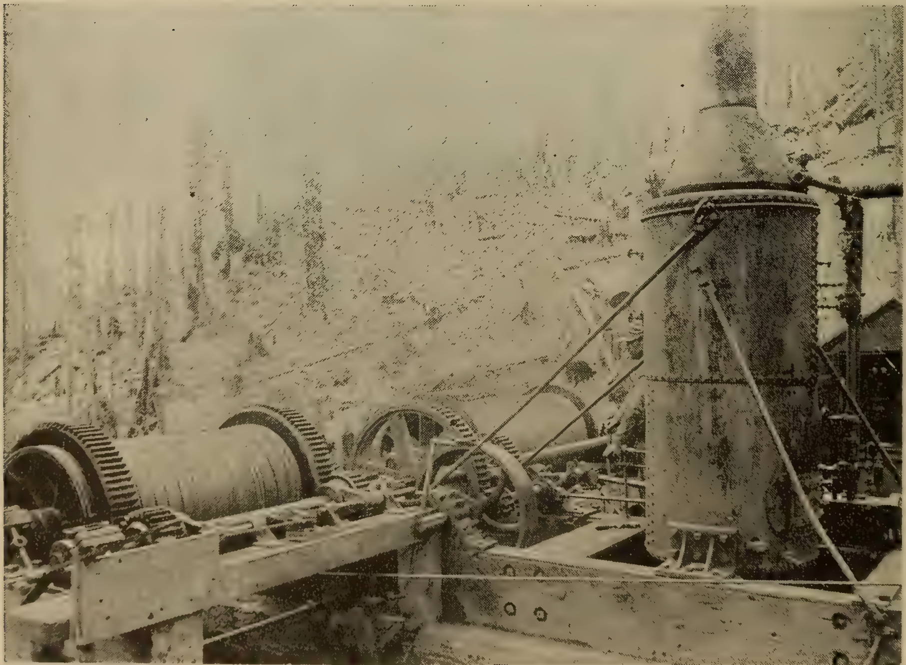
In 1875 a railroad for logging purposes was projected, to run from the northern arm of Humboldt bay into the forest beyond Mad river. The experiment was watched with a great deal of interest, and not a few predicted a total collapse of the scheme, and laughed at it as wild and visionary. But it was finally completed, proving a decided success, and leading to the building of many others, both in this county and elsewhere. The railroad is now almost as great a factor in the problem of lumber making as the mills themselves. As a natural result, the old-time picturesque methods of "driving" logs, and of handling them by means of the slow and cumbersome tramway, are becoming things of the past. The excitement and the sound of rushing waters heard when the dam was broken, or when the "jam" was loosened, and the dismal creak of the tramway truck, are forgotten in the rumbling of the car wheels and the screech of the locomotive. The mills no longer shut down for want of logs; rafts can be made up and towed to the booms any day of the year from the "landings" of the various railroads. All the mills on Humboldt bay are thus supplied with logs, while those located in the timber send their lumber by rail to tide-water points on the bay, there to be shipped to San Francisco or foreign ports. This improvement in transportation of course means improvement all along the line. The axe is giving place to the saw for felling trees, and the



A MODERN STEAM LOGGING OUTFIT.



TYPES OF "BULL DONKEYS."



patient but "pokey" ox team is making way for the steam "donkey." This "donkey," or winch, can be planted in the bottom of a gulch, or on the hill-side or hill-top, moving logs up or down, or in any direction, and is itself easily moved from point to point by its own power.

All these, and many other improvements that might be mentioned, are gratifying to the lumberman, no doubt, whose business is to pull down the forest. These are his means of destruction. There is something of the picturesque in the lumber camps, but there is little in the life of the woodsman to make it attractive, and only those who are accustomed to hard work find their way thither. The camp consists of half-a-dozen or a dozen rough shanties, each provided with sleeping bunks, besides a cook-house, which is the imposing structure of the settlement. In this "mansion" meals are served to all the workmen on the claim, the long rough table being abundantly supplied with wholesome food by the company or individual who "runs" the camp. The cook—usually of the sterner sex—is the oracle of the camp, occupying about the same social position as does the bar-keeper of a mining camp. He is less fastidious than his social prototype, but is quite as important a personage. Next to him, perhaps, is the ox-teamster. Then come the choppers, the sawyers, the chain-tenders, water-carriers, etc., the crews consisting of from twenty to fifty men. The programme of exercises is about the same in all camps—breakfast at six; work; dinner at twelve; work; supper at six; smoke; go to bed. Not an exciting life, but a healthful one to those who escape accident; for now and then some poor fellow meets death between the huge logs, or beneath some falling tree or limb, or from a flying "dog" which slips its hold.

Breakfast (or dinner) over, all hands make their way up the hill-side or gulch where they have been at work for weeks or months, and where axes and saws and jackscrews have been left from day to day. The boss of the camp directs operations, and the work of destruction goes on with more system than one would imagine. Trees cannot be felled hap-hazard—there are too many of them for the ground space. The great logs that have fallen during the storms of the past, and which lie in every direction, must be avoided—perhaps they must be removed. A block is made fast to some neighboring tree or stump, the rope or chain passed around the log. Meantime the ox-team is toiling up the steep slopes, or hauling the heavy logs down the smooth ways prepared for them, the water-boy, with his buckets, in constant attendance, dashing a bucket of water as a lubricant in front of the slow-moving log at brief intervals. From one direction comes the sound of axes; from another the hissing sound of saws, or the stentorian voice of the teamster, or the crash and jar of a huge tree as it falls among its prostrate fellows. If you follow these sounds through the brush, or over and under or around logs which you cannot scale, you will presently come upon—it may be a tree that will fall to-morrow, or perhaps the next day; or it may be only an ordinary log of six or eight feet in diameter. Whatever its dimensions, it is being cut into lengths of twelve, sixteen or twenty-four feet, preparatory to hauling to the "landing," if they are to be carried by railroad or tramway; if they are to be "run," they may be hauled at once to the bed of the creek, there to await the winter freshets. If the logs are very large and too heavy to handle—as is frequently the case, especially with but-logs—then the auger is brought into use, cartridges inserted and the log blasted, when it is dragged away in sections to the dumping-ground—either the landing or the dry creek bed.

Let us follow one of them. We can take our time and have plenty of opportunity to note the various forms and shades and tints of foliage and tree-trunk and ferns peculiar to the forest, for the ox-team is not a rapid transit concern, particularly when it is ballasted with a redwood log. When the "dogs" and chains have been made fast and

everything is in readiness, your attention will be attracted to the teamster, who seems, all of a sudden, to be under a full head of steam, so full of animation is he as he prances along the line of his oxen, shouting at the top of his voice—and that is no mean altitude—until he reaches the leaders. Here he makes a lunge at the ribs of the "near" ox with his goad-stick, lifting the poor brute nearly off his feet, and forcing from him a dismal, agonizing blah! Almost at the same instant the cudgel is brought down with a whack on the sharp back-bone of the "off" leader, and then is just as promptly transferred to the ribs of the next "near" ox, and so on down the line. Of course the log starts. But the cattle soon settle down to a steady pull, and you must watch sharp in order to note progress. The teamster occasionally breaks out into a wild gush of profane melody, accompanied by whacks and prods with the goad-stick; the water-boy (who is usually a man) scatters a bucket of water in front of the moving log now and then to assist locomotion, and in time the "landing" is reached. This landing, you will see, is a space fifty or sixty or may be one hundred feet long, which has been leveled and covered with small logs placed at right angles with the railroad or creek, and from which the logs are rolled upon flat cars, or dumped into the creek-bed or into the water of the slough, as the case may be. Reaching this landing or platform, the chains are removed from the log and the cattle turned back to the hill-side. Two or more men with jack-screws then roll the log to some convenient place on the landing, or directly upon the flat car in waiting. If the logs are to be "run," they are piled up in the bed of the stream, sometimes to a considerable height, and for half a mile or more up and down the stream, as shown in the illustration. Here, it will be noticed, all the logs are bare, having been stripped of their bark before they are hauled. There are men in every "crew" known as "peelers," whose business it is to do this work. The bark of the redwood, as I have said, is often a foot or more in thickness. It would be of no use to the lumberman, and would interfere with sawing in the mills, so it is peeled off and left in the woods, or used to bridge over bad places in the roads, for which it is an excellent material.

Having seen one of these dumps, or landings, toward the close of the cutting season, with its countless number of huge logs, in all of which scarcely a limb or knot is visible, and remembering that all along the forest line where lumbering is carried on the same work is being done, one is inclined to doubt the wisdom of such an apparent wholesale destruction of the forest; one is apt to entertain the opinion that here in one of these great heaps of logs is material for all the lumber that will be needed for a lifetime. But let us follow these logs, or at least a raft or train-load of them, to their destination at the mills; let us see how they are carved and sliced up, and made ready for the use of man; let us see what manner of things these mills are, which devour so much raw material.

They are located on Humboldt bay and at Trinidad—chiefly on Humboldt bay—are twelve or fifteen in number, and turn out from forty to one hundred thousand feet of lumber each per day, exclusive of shingles, shakes, pickets, etc. Here the ships are loaded for San Francisco, Mexico, South America, Australia, and wherever else the lumber has a market. Here the hum of the saw and planer and the rattle and noise of the machinery has been constant for twenty years, yet one is hardly able to tell where the logs have come from to keep the mills busy for all these years, so little does the work of the woodsman show to the casual observer.

Whether the logs are "run" or carried by rail, the object is the same—to get them to some tide water point where they will be available at all times for the use of the mills. Some deep slough or arm of the bay is usually chosen as a railroad terminus. Here a landing is built of heavy logs, with an incline toward the water, the inner line of the landing close to the track. Over this

landing, with the aid of jack-screws —without which it would hardly be possible to handle them—the logs are rolled into the water, where they are made up into rafts from time to time, and towed to the various mills, where they are stored in the booms for use. From these booms or ponds the logs are hauled up an incline into the mill by a great chain attached to a low iron car, which is first lowered into the water and the log floated upon it and made fast. The sawyer being ready for the log, he lifts or rolls it to its place upon the carriage by means of a huge derrick ; the log is secured, the lever is thrown over and the log moves up against the double circulars, which cleave their way through the wood as if it offered no resistance. The first slab is quickly removed, disclosing the deep, rich color of the redwood, its straight grain showing no blemish or knot from end to end of the log. The slab is thrown upon a low car and wheeled away by two men to the waste-pile beyond the mill, where a fire is constantly burning ; or, as is quite common now, it is carried on rollers to a "pony saw" and reduced to stove lengths, to be sold for a trifle as firewood—a poor article, though it will burn when thoroughly seasoned. Another turn of the lever runs the carriage back, and the log is again brought in contact with the saws. This time a board or plank is laid off, perhaps twenty or, it may be, fifty inches wide (for these mills turn out lumber of any desired width up to fifty inches, of any thickness and of almost any length), and then another and another, until the log is no more. Meantime another has crept up the incline from the boom below, and is soon on the carriage undergoing the same rapid process of reduction. The boards have passed

ROLLING A 17-FOOT LOG BY STEAM POWER.

through various machines—the planers, the edgers, etc.—and have gone down the chute to the wharf below, where great piles of the same clear, perfect lumber awaits shipment.

The process is not materially different from that of lumber mills everywhere, the distinguishing feature being the immense proportions of all the machinery used. Such logs as come from the redwood forest cannot be cut and handled by saws and machinery of ordinary dimensions. Everything in and about the mill—the mill itself—must be of the same giant proportions as the logs that are brought to them. And this reminds me of a proposal from a Pittsburgh (Penn.) firm, some years ago, to fit up a new mill on Humboldt bay. The firm stated that it was their special business to fit up saw-mills, and forwarded cuts and dimensions of the various machines they were prepared to furnish. The millman informed the Pittsburghers that he was not planning a match factory, and sent dimensions of what the mill would require. This seemed to be a puzzle to the Eastern builders, and presently one of the firm came out as a sort of investigating committee. He soon discovered that their heaviest machinery must at least be double in strength and capacity to be of any service to the manufacture of redwood lumber. The investigation resulted in new patterns, and machinery has since been built especially for this trade.

In these mills, as in the woods, one is quickly impressed with the fact that the work is not the easiest in the world, nor the most desirable to a "thin-skinned" person. The incessant din of machinery, the flying belts and pulleys, the endless chains, the rattle and jar, the escape of steam, not to mention the inclines and chutes and other contrivances which seem to be ever waiting to swallow up the unwary, must make it a perfect pandemonium and place of fear and dread. At least to the visitor it seems all this. Here a log comes creeping up from the mud and slime of the boom. Behind you the great saws are screeching as they hurry through the log, which may have been growing yesterday miles away in the forest; to your left a small flat car, propelled by two men, bearing away bits of slab and small rubbish to a mild sort of Gehenna, which is ever kept burning, fifty or sixty yards beyond the mill. From the saw-carriage runs an elevator which carries the sawdust down to the furnace-room, or directly into the furnaces. At the other end of the mill are saws and machines for various purposes and of various sizes. To your right the great planers send out their demon-like yells as they take the rough surface from the boards. And then the chutes, down which the lumber scurries away to the wharf below, there to be sorted and piled and loaded upon ships or cars or wagons, and started out upon its mission among men. To the visitor, at least, all this and much more that can hardly be described makes the most perfect state of confusion imaginable; and yet the business goes on as smoothly as possible, and men work away as quietly as if they had no such things as ears or nerves.

An observant person soon discovers that nearly all the lumber piled upon the docks—in fact nearly all that is made—is what is known to the trade as "clear" lumber—that is, without knots or defects of any kind; and upon inquiry he will find that about seventy per cent. of manufactured redwood is of this description, whereas not more than twenty or twenty-five per cent. of Eastern lumber is clear, the other seventy-five or eighty per cent. being merchantable of refuse—that is to say of second and third grades, as understood by lumber dealers the world over. Here is one great advantage of the redwood over other lumber-producing woods. The trees grow almost without limbs, and, as a result, make clear lumber. Much of this beautiful clear stuff we have seen on the wharf is rough (undressed), and is destined for foreign markets.

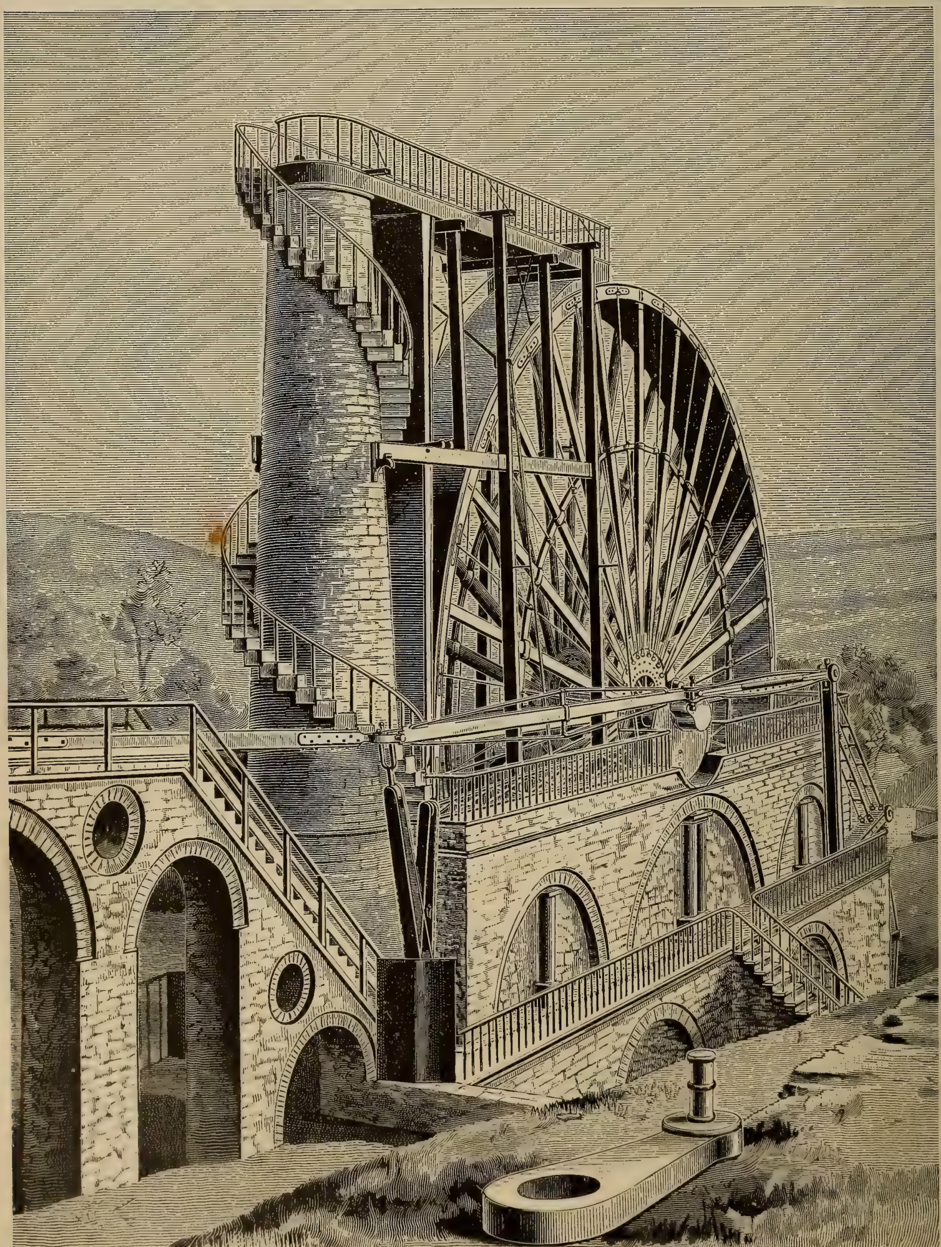
In local and domestic trade this lumber has really no competitor. It is made into all conceivable shapes and dimensions, and is used for all conceivable purposes, architects and builders

ordering by ship-load or wagon load, as their immediate wants may dictate. As already stated, lumber in California means redwood, whether for building purposes, outside and in, or for casks and wine-vats, for railroad ties, for planking above or below the ground surface, for pickets, shingles, moldings, brackets, doors, or for furniture and cabinet-work. There is such variety to this redwood—variety as well of color as of grain and texture (hard or soft)—as to make it very serviceable to the furniture and cabinet-maker. Of late there is being used extensively in these branches what is known as buhrls, or huge knots that sometimes grow on the tree-trunks, frequently eight or ten feet in length or breadth. These buhrls—harder than iron-wood—consist of innumerable small birds'-eyes or tiny knots, so compactly put together as to leave no grain whatever. The wood of these buhrls, when worked, is of a rich, dark mottled brown, and highly ornamental. Side-boards, tables, mirror-frames and other articles made from these knots are of the most exquisite beauty, and are as durable as iron. It is destined to be used more extensively for veneering purposes, for I doubt if any wood would give better results.

The best part of the tree for these purposes is that at the base—just where the trunk joins the root. For years it was the custom in felling trees here to leave a stump of ten or twelve feet ; it is still done in many cases. I cannot explain why—I only know it is so. But this stump, so long ignored, is, for many reasons, the best part of the tree; it is more compact and solid, is darker in color and more durable—it is, in fact, indestructible, as it will neither burn nor decay—a fact fully appreciated by those who have attempted to clear off redwood land for tillage. Among these stumps of the old worked-out logging claims there is a rich harvest for future reaping. From them can be obtained the very best of material for veneering, while many, perhaps a large proportion of them, are well worth working for the choice lumber they contain. This harvest will not be reaped to-day; the greater harvest of the forest demands the energy and enterprise of man. But the future will take care of it—it will not go to waste. Much of the timber which is now neglected—the smaller growth of two to three feet diameter—will be utilized, and some pains may be taken to preserve and protect the younger growth of the forest. This is problematical, however, as the history of all lumber-producing forests has been the same—they are made to yield to present needs, regardless of the future.

An effort was made some years since to induce the Government to make two or more reserves in the heaviest-timbered portion of the belt; but the effort failed, and the whole forest has either passed into private hands or is open to pre-emption and destruction. Not only is every available appliance used for getting out timber in the quickest and easiest manner, but the brand is frequently applied for the purpose of clearing away the rubbish and dense tangled undergrowth which would render logging well nigh impossible. While these brush fires do not affect the timber (for it is practically fire-proof), they must retard the growth of the seedlings and injure, if not kill outright, the tender shoots just putting up from the ground. Little or no effort is made to preserve the trees too small for present use—trees of one, two or three feet diameter. If they stand in the way, clear them out; if they happen to be crushed under a fallen tree, no matter—there are enough and to spare for present needs. Why should they not make way for man's insatiate lust for gold?

And so I ask, how long will the redwoods last? A few years at most. But in that brief time men will build their castles and their thrones of power upon the ruins of this mighty race of giants, with the one regret that there are no more to conquer.



THE GREAT 72-FOOT OVERSHOT WHEEL AT LAXEY, ON THE ISLE OF MAN, ENGLAND.

THE FERRIS AND OTHER BIG WHEELS.

By F. G. Coggin, M. Am. Soc. M. E.

THE FERRIS WHEEL.

A VERY wise man of antiquity, a distinguished author, and, as there is reason to suppose, one somewhat versed in architecture and engineering, once wrote, "Is there anything whereof it may be said, 'See, this is new?' It hath already been of old time which was before us. There is no remembrance of former things; neither shall there be any remembrance of things to come with those that shall come after." Could the author of these words, with all his knowledge of what had gone before, go into the patent offices of the country, and others, and look over the rejected claims upon the faces of which had been written "no novelty;" could he have visited the great World's Fair, and listened to the claims for new devices, new designs, new principles; could he have looked over the papers and magazines of the day and noted the claims of the enterprising writers, or could he, perchance, have read any of the several articles describing the much-talked-of Ferris wheel, he, doubtless, would have proclaimed anew his utterance of some twenty odd centuries ago, "There is no remembrance of former things."

In much of what has been written of this greatest attraction of the Midway Plaisance at Chicago, whose towering rims were visible for a long distance in all directions, and, in the night, with its illuminations, made one almost feel as though one of the constellations of the heavens had dropped down to visit the Fair, and whose revolutions marked epochs in the lives of those who swung around its great circle, there are statements which will not bear the light of history. We would not for a moment detract from the fame that will be linked to the name of the designer of the great wheel, transient though it may be, for it cannot long hold the claim of being the biggest wheel in the world; nor would we question the "daring" and "brilliancy" of the exploit, nor the "American dash" which compassed the work in so short a time, although, given the facilities, and the capital behind it, there are many engineers who would have accomplished the same result. We would not even dare to question the idea that such a project was evolved "from a chop dinner," as one writer put it, during the enjoyment of which all the details of the great structure were formulated to such a nicety as to require no change in the subsequent construction, because, this will hereafter be an inspiration to the rising generation of engineers, who, after struggling without result upon some great problem, can, as a last resort, a forlorn hope, fall back upon a chop dinner, the efficacy of which has so providentially been discovered. Admitting all this, some statements have been made which, in the interest of truth, call for correction.

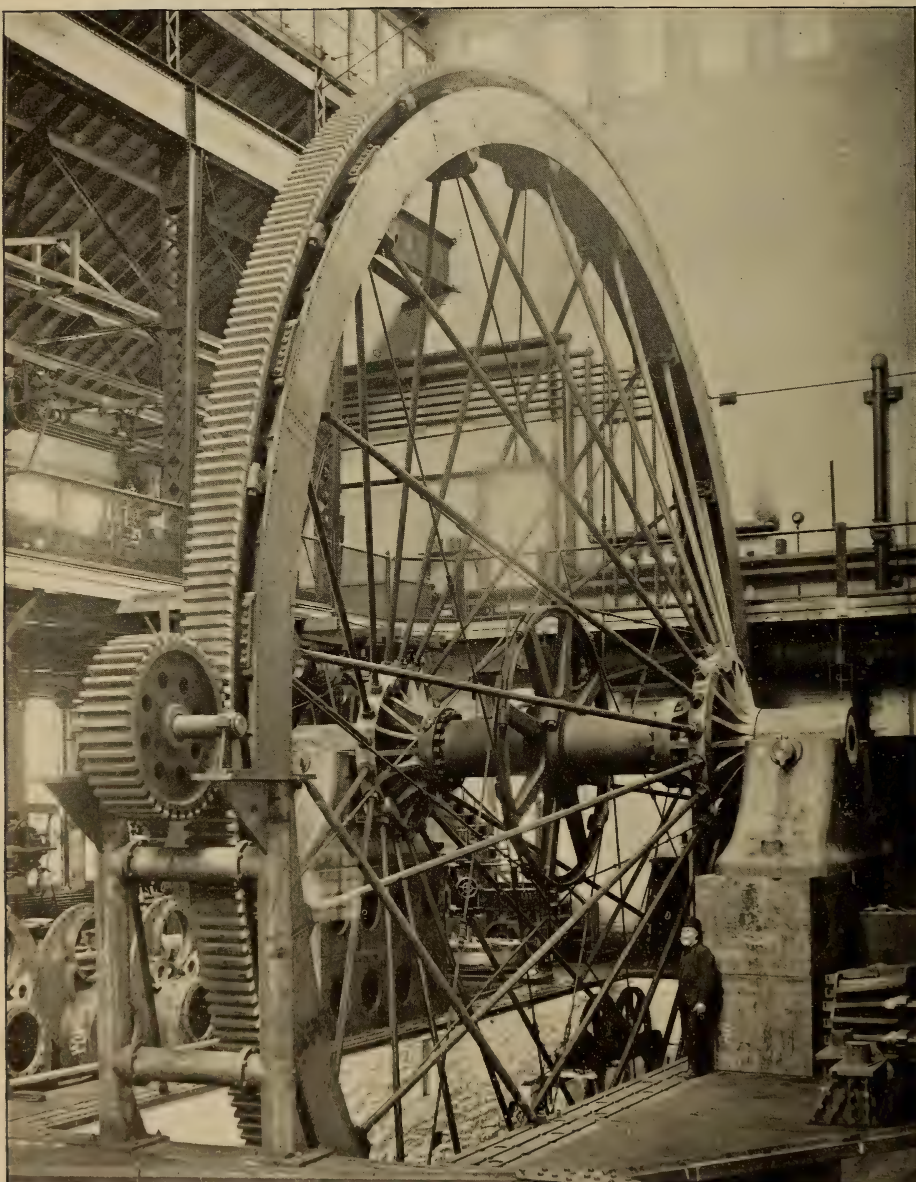
In referring to the wheel as a triumph of modern engineering, one writer, in The Review of Reviews said:—"It brings into play a new mechanical principle." After stating that the wheel was to be a perfect "pinion wheel," 250 feet in diameter, he continues, "It was to be, moreover, a 'tension' wheel, that is to say, a wheel with 'tension' and not solid spokes." That this "tension" principle was regarded by the designer as one of the chief points in the wheel, is shown in the same article where he was made to say,

THE FERRIS WHEEL, 250 FEET IN DIAMETER.

"You know that the wheel is not only a perfect pinion, but a tension wheel as well, and these, I suppose, may be regarded as the chief points." Still further, the writer said :—"Perhaps it will give some idea of the measure of Mr. Ferris' achievement, to note that the tension wheel is still a novelty, even in the engineering world." These statements reflect upon the knowledge and intelligence of a very large part of the engineering world, the mechanical engineers, who are more or less familiar with the fact, that in the construction of wheels the tension principle was well known and practicably applied 40 years before the designer of the Ferris wheel was born, and that for the last 40 years it has been prominently in practical use in this country.

The two great sand wheels used by the Calumet and Hecla Mining Company at their stamp mills in Lake Linden, Michigan, for the purpose of raising their waste sand and water, so as to carry the sand farther into the lake, are built on the tension principle, applied, to be sure, in a different method than that used in the Ferris wheel, but no less a complete embodiment of the principle. These wheels were designed in 1888 by Dr. E. D. Leavitt, of Cambridgeport, Mass., the consulting engineer of the Calumet and Hecla Mining Company. They are 54 feet in diameter over all, and 11 feet wide, having a capacity to raise in twenty-four hours 30,000,000 gallons of water, and 2500 tons of sand. The illustration on the next page very clearly shows the wheel without the bucket rims, as it was set up in the shop of the Dickson Manufacturing Company's works, where it was built. The centre rim is composed of cast-iron segments, bolted together, and to this one of the ends of the tension rods are attached, the other end being connected to the outside hubs in such a way as to provide for adjustment. The hubs and the gudgeon are in one casting. To the centre rim is bolted the segmental gear into which meshes the pinion, both pinion and gear being cut by special machinery made for the purpose. The gears are the largest cut gears in the world, and with the proper adjustment of the tension arms, the wheels run with perfect truth. These wheels were demonstrating the utility of the tension principle for years previous to that memorable "chop dinner," and their design, construction and practical working were well known throughout the country, and were the subject of discussion among many engineers of prominence. But Mr. Leavitt laid no claim to the discovery of a new principle, knowing full well of a water wheel, built upon the same principle, which had then been running in this country nearly 40 years.

This wheel was designed by Mr. Henry Burden, so well known as one of the founders of the Burden Iron Co., of Troy, N. Y. As early as 1840 he had designed and constructed a water wheel on the tension principle. This wheel was run nearly 10 years, but coming to extensive repairs, on account of defective timber, a new one was built on the same principle in 1851. Its diameter is 62 feet over all; width, 22 feet, and its weight is about 230 tons. It has 264 radial tension rods and two tangential rods. It is the largest overshot wheel in the United States, and with a limited amount of water transmits about 550 horse-power by a gear on its rim through a pinion to the main shaft, and after 43 years of constant running, is still in perfect working condition. It is not at all likely that Mr. Burden claimed to be the originator of the tension principle, which he used in the construction of his water wheel. Doubtless he, with most engineers of that time, and since then, was familiar with the writings of that eminent English engineer, Sir Wm. Fairbairn, and especially with his "Treatise on Mills and Mill Work." His long and large experience in mill work, including water wheels, gave him and his writings a very wide reputation among engineers all over the world, among whom he was regarded as an authority in various branches of engineering. In volume one of the the third edition of his "Mills and Mill Work," he describes and illustrates some improved, iron, high breast



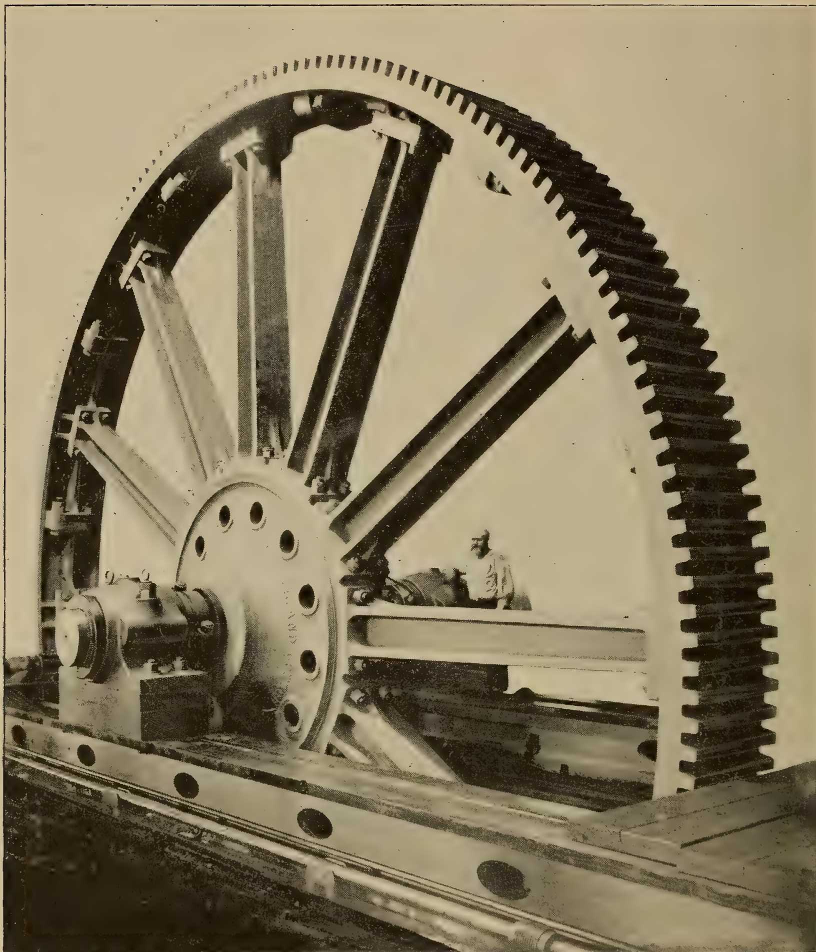
ONE OF THE GREAT CALUMET AND HECLA SAND WHEELS, 54 FEET IN DIAMETER, BUILT BY THE DICKSON MANUFACTURING COMPANY, SCRANTON, PA.

wheels, designed by himself and built at the works with which he was connected. They were erected at the Catrine Works, in Ayrshire, between the years 1825 and 1827, and in 1851 he wrote that "these wheels, both as regards their power, and the solidity of their construction, are, even at the present day, among the best and most effective structures of the kind in existence. They have now been at work upward of 30 years, during which time they have required little or no repairs, and they remain nearly as perfect as when they were erected."

These wheels were 50 feet in diameter and about 11 feet wide, and transmitted their 240 horse-power from internal segmental gears attached to the rims, the gears being 48 feet 6 inches diameter, of 15-inch face, and 3¼-inch pitch. Speaking further of the practice of using this principle in the construction of wheels, Mr. Fairbairn said that it was "the principle most generally practiced in the construction of improved iron water wheels." The two chief points in the construction of these wheels are identical with those which 70 years later were claimed as new in the Ferris wheel, and which, meanwhile, had been successfully applied by both Mr. Burden and Mr. Leavitt. But even Mr. Fairbairn claimed no originality in the use of this principle, but wrote that "it was reserved for Mr. T. C. Hewes, of Manchester, to introduce an entirely new system in the construction of water wheels, in which the wheels, attached to the axis by light wrought-iron rods, are supported simply by suspension." He wrote further:—"I am informed that a wheel on this principle, in Ireland, was actually constructed with chains, with which, however, from the pliancy of the links, there was some trouble; but the principle on which the wheel was constructed was as sound in theory as economical in practice, and is due originally, it is said, to the suggestion of Mr. William Strutt, and was carried out 50 years ago,"—(the latter part of the 18th century)—"by Mr. Hewes, while at the same time Mr. Strutt applied the principle to cart wheels, some of which, then put together, were for a long time in use." According to this statement, the bicycle of to-day will have to take a long backward look to see its prototype in the wheels of Mr. Strutt. Mr. Fairbairn writes further:—"Mr. Hewes employed round bars of malleable iron in the place of chains, and this arrangement has kept its ground at the present time as the most effective and perfect that has yet been introduced."

Doubtless a great many more overshot, breast and undershot wheels would have been constructed upon the tension principle, but at about the same time that Sir William Fairbairn designed the Catrine wheels, Poncelet, Fourneyron, Borden, Jonval and other hydraulic engineers introduced the various turbine wheels, known by their names. The advantages which these wheels presented, such as small size, cheapness, high speed, possibility to utilize high heads, facility of introduction into places inaccessible to other wheels, high efficiency and ready governing, made their introduction easy and rapid, and they have crowded out the class of water wheels just mentioned. It is apparent, therefore, that the tension principle in the construction of wheels, big or little, is neither new nor experimental, but that for nearly a century, if not longer, it has been well known, has held its place as the highest type of engineering in that line, and has at intervals during all these years been commonly, practically, and successfully applied by engineers of high repute in both England and America, and it seems preposterous to assume that the principle is a novelty to the engineering world of to-day.

It is interesting here also to bear in mind the great overshot water wheel at Laxey, on the Isle of Man, in the Irish Sea, off the west coast of England. This wheel is unquestionably the largest and most expensive water wheel ever built. It is 72 feet 6 inches in diameter, and is supposed to develop about 150 horse-power, which is transmitted several hundred feet by means of wooden trussed rods having supports



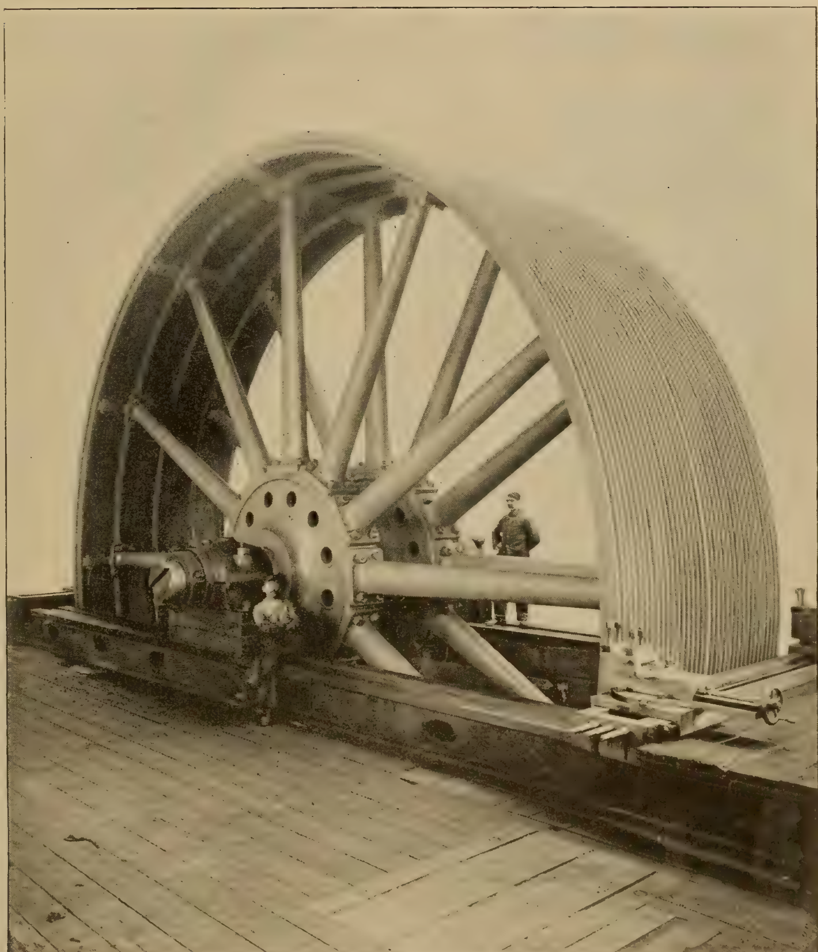
MACHINE CUT SPUR GEAR, 30 FEET 6 INCHES IN DIAMETER, AT THE KIMBERLY DIAMOND MINES, SOUTH AFRICA, BUILT BY THE WALKER MANUFACTURING COMPANY, CLEVELAND, O.

at regular intervals, to the bottom of which are attached small wheels running on iron ways, for the purpose of lessening friction. The power thus transmitted, operates a system of pumps in a lead mine, the duty of which is raising 250 gallons of water per minute to an elevation of 1200 feet. The water is brought some distance to the wheel in an underground conduit, and is carried up the masonry tower by pressure, flowing over the top into the buckets. This great wheel was constructed some 40 years ago, and is said to have been running continuously during all this time. It is the great attraction of the place, hundreds of visitors making the trip to the island every year to see it.

Before concluding, still another wheel must be mentioned,—the big tension wheel now being erected at London at the Earl's Court Exhibition which will strip the Ferris wheel of its claim of being the biggest wheel in the world, rising, as it will, to a height of over 300 feet, with accommodations for 1600 people, as against the Ferris wheel's 250 feet and accommodation for 1368 people. But it is not only in size that

the "Gigantic" wheel, as it will be called, will differ from the "Ferris." The structures which carry the axle-bearings of the former are very different in appearance from those of the latter. The English wheel will be carried on two towers, 175 feet high, having at their tops, and at intermediate stages, saloons surrounded on three sides by balconies. The tops of these towers will be accessible by elevators as well as by stairs, and they will be connected by a passage running through the axle of the wheel. This is to be 7 feet in diameter, and will be built up of mild steel bars and plates, while in the Ferris wheel the axle is a solid steel forging, 32 inches in diameter.

Another point of dissimilarity is in the manner of driving. The Ferris was provided with a cast-iron spur rack, with teeth of 24-inch pitch, worked by a chain driven by a steam engine. The "Gigantic" wheel, however, will be driven by wire ropes, 1⅞ inches in diameter. There will be two such ropes, one on each side of the wheel passing around grooves on the edges, but only one will be used at a time. Power for driving will be sup-



ROPE WHEEL, 32 FEET IN DIAMETER, 8 FEET 4 INCHES FACE, BUILT FOR THE BROADWAY CABLE RAILROAD, AT NEW YORK, BY THE WALKER MANUFACTURING COMPANY.

plied by two 50-horse-power dynamos, one of which will be sufficient to do the work, enabling the second to be held in reserve for emergency.

Each of the supporting towers stands on four concrete blocks, 15 feet deep, and about 15 feet square at the top. The cars, of which there are to be forty, will each be 25 feet long, 15 feet wide, and 10 feet high, and will accommodate about 40 passengers. There will be eight platforms from which they can be entered, so that the wheel will stop five times during each revolution.

From what has been said it is quite evident that the question put by Solomon twenty-eight centuries ago, is as pertinent now as it was then : "Is there anything of which it may be said, 'See, this is new?'"

MECHANICAL DRAFT.*

By William R. Roney, M. Am. Soc. M. E.

THE importance of good draft, natural or artificial, for supplying sufficient oxygen for the economical combustion of fuel, has long been recognized by intelligent engineers. The gain, both in efficiency and capacity, obtained by the rapid and energetic combustion of the various kinds of coal, and the resulting high furnace temperatures, is well established, but its importance has been generally conceded only within a few years. The wonderful stimulus which the development of electrical industries has given to the building of compound engines has necessitated higher boiler pressures, and this, in turn, has greatly increased the use of boilers of the water-tube type. While high initial temperature in the furnace is essential to the best economy with all types of boilers, it is especially so with water-tube boilers, with their large amount of heat absorbing surface in close contact with the products of combustion, as, otherwise, the temperature of the gases will be lowered below the point of ignition and will pass to the chimney only partially consumed. To obtain this high furnace temperature requires draft sufficiently strong to deliver an abundant supply of oxygen to the furnace.

Two well known means are used for accomplishing this result, viz.: natural draft, produced by a column of heated gases in a chimney of suitable proportions; and forced draft, obtained by mechanically creating a pressure under the grates with a blower or fan. A third means, less widely known, is mechanical exhaust or induced draft, produced by a suction fan so arranged as to draw the waste gases from the furnace and discharge them into a short stack sufficiently high to clear the roof of the building.

Although the idea is by no means a new one, yet it is only within a few years that mechanically induced draft has been much used or installed on a large scale. Previously it had been used, with a few exceptions, for the purpose of improving poor draft by helping out an insufficient or an overloaded chimney. On account of the height of the stacks being necessarily limited, artificial or forced draft has been used on ocean steamers for many years. Here the usual method of producing artificial draft is by rapid-running pressure blowers discharging under the grates, or into the fire room, which is made practically air tight, and maintaining an air pressure in the room of 2½ to 3 ounces. This method of producing artificial draft is at an expense for power to drive the high-speed blowers, which would not be considered for

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a moment except on shipboard, where the limited space, as a rule, prohibits the use of large, slow-running fans and where economy is not the most important consideration. Experiments in the use of mechanically induced draft are now being made on some of the Atlantic liners. The steamer City of Berlin, of the American line, was fitted up last year with large steel exhaust fans, driven by direct-connected engines, and having a capacity in cubic feet of air per minute sufficient to produce a draft equal to 3.5 inches of water. Connections were made to the smoke flues, so that the gases were drawn from the furnaces through a by-pass and discharged into the steel smoke stacks. The results obtained are not yet made public, as they are still being tested experimentally.

The largest and most successful applications of mechanically induced draft have been made in connection with feed-water heaters designed to utilize the waste heat of the flue gases, and known as fuel economizers. This form of feed-water heaters has been manufactured in England for over fifty years, and in the United States for three or four years. They have, however, been imported for many years, as their value as a fuel saving device is well established. Their successful operation is however so dependent upon good draft, that no well-informed engineer would think of installing an economizer without making provision for much better

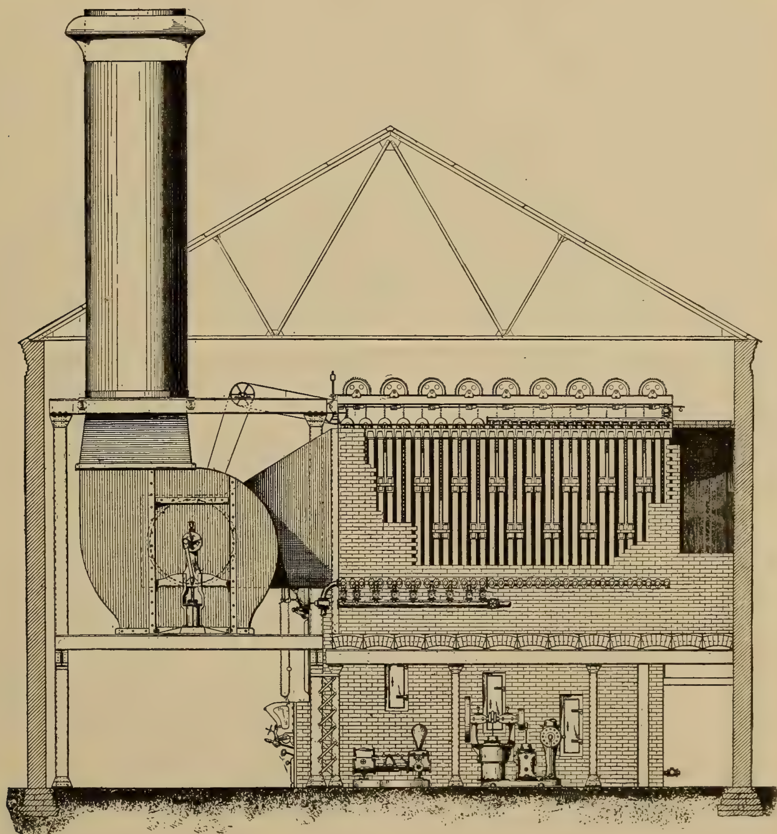


FIG. 1.—CROSS SECTION OF A TYPICAL BOILER-HOUSE, SHOWING BOILERS, STOKERS, ECONOMIZER, MECHANICAL DRAFT, FEED PUMP, AND CONDENSER.

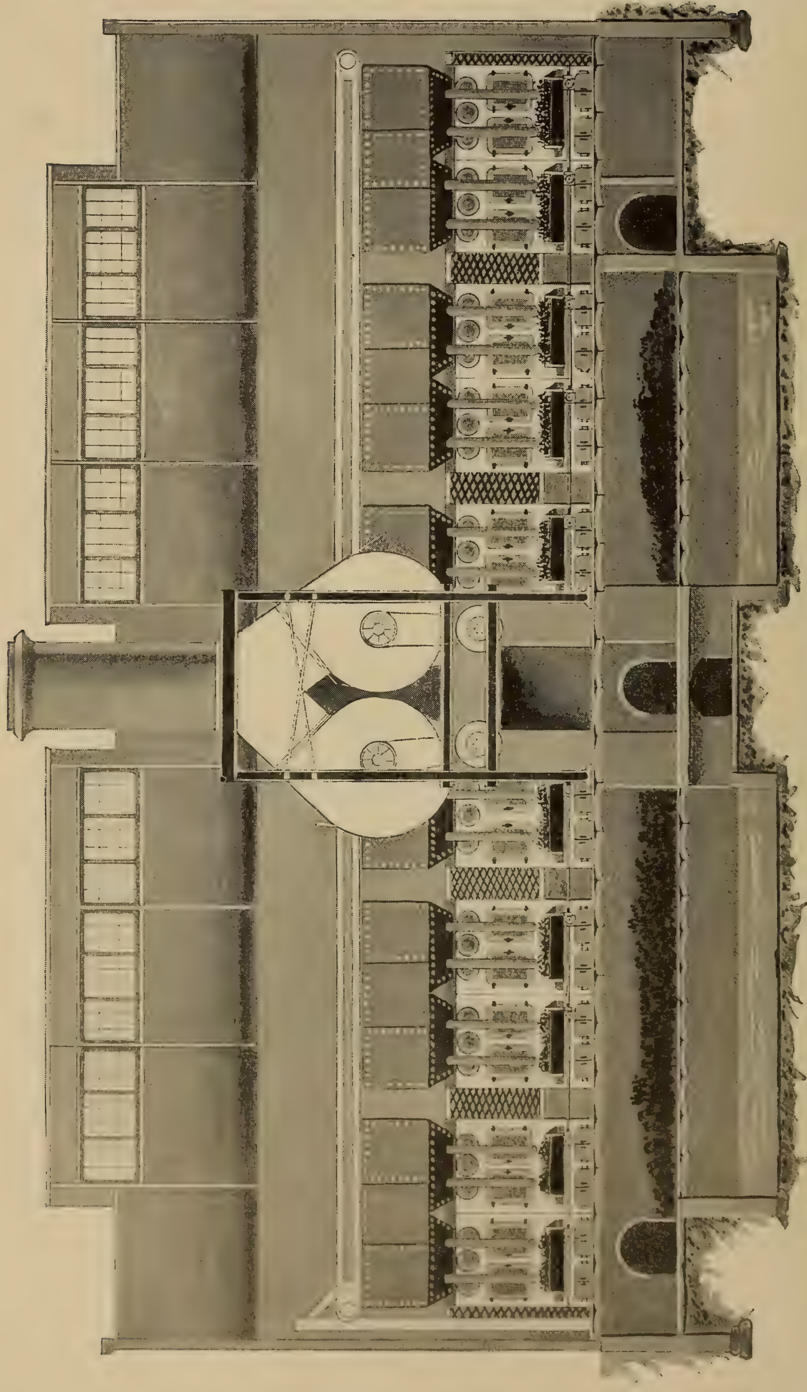


FIG. 2.—LONGITUDINAL SECTION OF BOILER ROOM, PHILADELPHIA TRACTION COMPANY.

draft than the boilers would require without it.

On account of the reducing effect on the draft caused by lowering the temperature of the gases and retarding their flow by the mechanical interference of the pipes, it cannot be considered good engineering to attach an economizer to a chimney less than 200 feet in height. In fact, the best working economizers in connection with chimneys are those where the chimney is considerably over 200 feet high.

The objections to be urged against high chimneys, as compared with mechanical exhaust draft when used with economizers, are: First, excessive cost, both on account of the height required and on account of foundations, which must of necessity be very substantial, and which may involve expensive piling and filling. Second, the space required for foundations, which may be very valuable, especially in large cities, or may be required for other purposes and which can with difficulty be spared. A chimney 250 feet high will require foundations not less than 30 feet square, and in some cases much more. Third, a certain minimum temperature of flue gases is required to produce an effective draft and to operate the boilers economically, and this fact limits the amount of economizer heating surface which can be used, and consequently the fuel saving obtained by use of the economizer. The same fact operates unfavorably at small capacities, which are often unavoidable, when the chimney must be built large enough for future increase of the boiler plant. Fourth, a chimney once built limits the maximum capacity of the boiler plant, and also is liable to be affected by atmospheric changes which may seriously impair its efficiency.

These objections to the tall chimneys which are so essential to the use of economizers, do not hold with mechanical draft. The first cost of a properly designed mechanical draft plant is very much less than that of a suitable chimney of equal capacity, usually averaging from 75 to 80 per cent. less, according to the size of chimney and character of foundations required. The fans and short stack require very little foundations, even less than that of an ordinary boiler setting. The space usually required for extensive chimney foundations can be utilized for economizers, and by elevating the economizers and fans upon beams and columns, the space underneath them can be used for pumps, condensers, etc., as indicated in Fig. 1, showing a cross section of a typical boiler house. The space thus saved is often of great value, especially where land is expensive.

Natural draft requires that the gases in the chimney be above a certain minimum temperature in order to secure a proper supply of oxygen in the furnace and a good combustion of the fuel, whereas with mechanical exhaust draft the amount of draft obtainable is entirely independent of the temperature of the flue gases, and when used in combination with a properly proportioned economizer, it is possible to lower their temperature to a point where the draft of even a very tall chimney would be practically destroyed. Mechanical draft possesses great advantages over natural draft in its flexibility and adaptability to both large and small capacities, and in its ability to meet sudden and excessive demands for steam, either by an extra turn of the throttle valve, or by an automatic regulator controlling the steam supply to the fan engine according to the boiler pressure. It is unaffected by atmospheric changes, furnishing the desired amount of draft irrespective of conditions of wind or weather. Operating independently of the amount of heat in the stack, it is possible to obtain a higher temperature of feed water in the economizer, and a lower temperature of escaping gases than could possibly be obtained with a chimney, and at the same time provide sufficient draft to maintain rapid and economical combustion of the fuel. There are undoubtedly many boiler plants equipped with economizers and chimneys, where the draft is so greatly reduced by the economizer, that it is an open question whether the saving in fuel by thus heat-

ing the feed water is not more than balanced by the loss due to imperfect combustion in the furnace ; and whether it would not result in a greater saving in coal to cut out the economizer and get better combustion, and a higher initial temperature due to better draft. Unquestionably the "black eye," which fuel economizers have sometimes received, has been often due to bad engineering, and to placing them where the chimney draft was none too good already, the result being, that they not only failed to show the economy that the purchaser expected, but so impeded the draft that the efficiency and capacity of the boilers were greatly impaired.

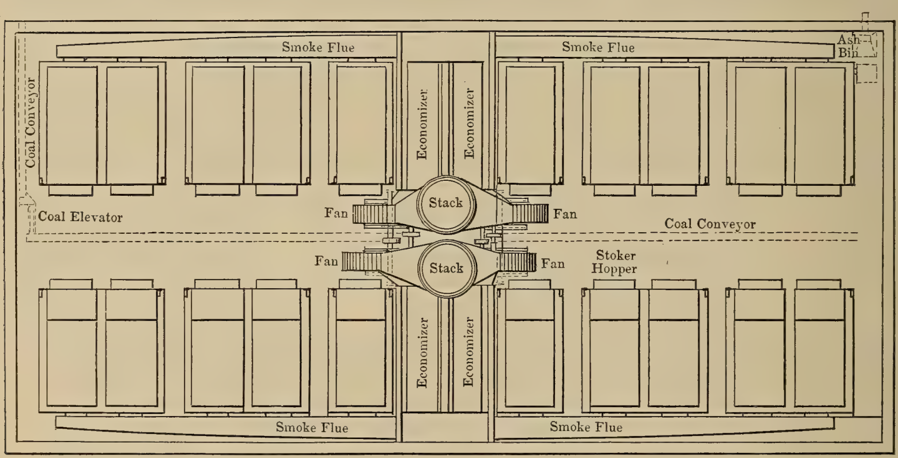


FIG. 3.—PLAN OF BOILER ROOM, PHILADELPHIA TRACTION COMPANY.

It was quite natural, under such circumstances, that the economizer should be neglected and allowed to foul up by the accumulation of sediment within the pipes, and of soot without, until it became a source of loss instead of economy. A chapter on the use and abuse of fuel economizers could easily be written, but—"that is another story."

A mechanical draft plant properly designed, with duplicate fans and engines of suitable construction, so arranged that one is always in relay, can be made so reliable that the boilers cannot be shut down by any ordinary accident. With the fans properly designed and proportioned to the work, the power required to operate them is so small as to practically have no effect on the economy obtained. The mistaken idea that prevails somewhat, even among intelligent engineers, regarding the amount of power required for mechanical exhaust draft, is probably caused by the well-known large amount of power required to drive the high-speed pressure blowers and fans used for forced draft. Mechanical draft handles a large amount of heated gases with slow-speed exhaust fans at a low pressure, and with a small expenditure of power. To illustrate :—the writer recently designed a mechanical draft and economizer plant for 6000 horse-power of water-tube boilers, providing duplicate large slow-running fans of special design, each driven by an independent engine, and each having a capacity, estimated in pounds of coal burned per hour, sufficient to develop 25 per cent. in excess of rating, or 7500 horse-power. The power required to drive one fan to do this work was six-tenths of one per cent. of the boiler horse-power developed ; or, estimated in coal per horse-power per hour, and at $3.00 per ton, the fuel cost of operating the plant one year was two per cent. of the estimated cost of the chimney originally planned for the plant. In other words, it would not pay to build the chimney so long as money was worth more than two per cent. per annum.

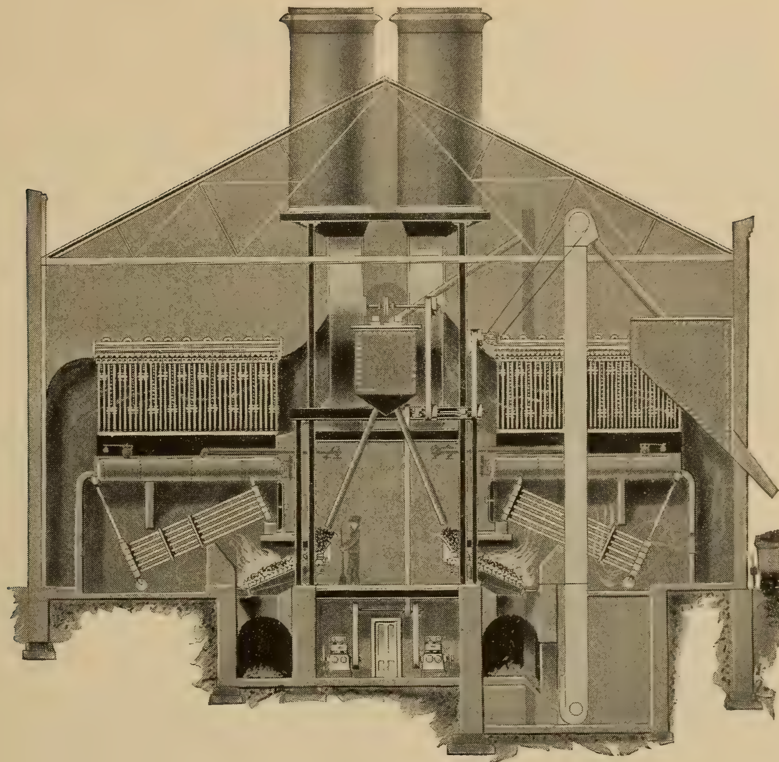


FIG. 4.—CROSS SECTION OF PHILADELPHIA TRACTION COMPANY'S BOILER ROOM.

In Fig. 1 the economizer is elevated upon columns and beams to provide for utilizing the space under the economizer for feed pumps, condenser, etc. The exhaust fans, of which there are two placed side by side, are equipped with direct-connected engines, only one engine showing in the illustration, the other being on the farther side. These fans and engines are of special design, with protected bearings, self-oiling and water-jacketed, to withstand the heat when the economizer is cut out for cleaning or for repairs, and the hot gases pass directly to the fans. They are so proportioned to their work as to handle a maximum amount of gases with a minimum expenditure of power. The arrangement of the economizer pipes and blow-off connections are worth noticing, in that they provide a means of blowing out the sediment which may accumulate in the pipes, and at the same time a complete circulation is maintained in the economizer. Many extensive plants are now in operation, or in process of construction, in various parts of the country, equipped with economizers and mechanical draft similarly arranged.

Figs. 2, 3 and 4 show a longitudinal section, a plan and a cross section of probably the largest plant of the kind yet built; viz., that of the Philadelphia Traction Company, Philadelphia, Pa. Two large power houses are in process of erection and partly in operation for this company; one of 7500 horse-power, and one of 6000 horse-power. The illustrations show the arrangement in the Thirteenth and Mt. Vernon street power house, where there are twenty Babcock & Wilcox boilers of 375 horse-power each, arranged in two parallel rows of ten boilers on opposite sides of the boiler room. The other station of 6000 horse-power is arranged similarly, except as to the number of

boilers. The gases from each row of boilers are conveyed by flues at the back to the centre of the boiler house, as shown in Fig. 3, drawn through the economizers and discharged into stacks by four large slow-running exhaust fans of special design. These fans are arranged in pairs, and are of such a capacity that two of them will handle the gases for the entire plant, thus leaving two in reserve. The fans are driven by duplicate engines and countershafts, so arranged that either engine will drive any one or more fans, as desired. The stacks extend but a few feet above the roof and are lined with brick to preserve them from the corroding action of the gases. The feed water is pumped through exhaust-steam heaters to the economizers, and thence to the boilers. At the Thirty-third and Market street station of the same company, the fans are driven by engines belted directly, one small engine to each fan. The economizers as shown in Fig. 3, occupy the space originally planned for two tall chimneys, one for each side of the boiler house. These chimneys were to have been 200 feet high with a flue eleven feet in diameter. Two of the fans are capable of producing a draft equal to that of the two brick chimneys originally planned. The power required to drive one of these fans, as the plant is now being operated, is exceedingly small, being less than ten horse-power for each 2000 horse-power produced, or less than one-half of one per cent. of the power developed by the boilers.

Tests of Economizer and Mechanical Draft Plants, Showing Initial and Final Temperatures of Flue Gases and Feed Water in Degrees Fahrenheit.

Plants tested.	Gases entering economizer.	Gases leaving economizer.	Water entering economizer.	Water leaving economizer.	Gain in temp. of water.	Fuel saving per cent.
1	610	340	110	287	167	16.7
2	505	212	184	276	192	19.2
3	550	205	185	305	120	12.0
4	522	320	155	300	145	14.5
5	505	320	190	300	110	11.0
6	465	250	180	295	115	11.5
7	490	290	175	280	105	10.5
8	495	190	155	320	165	16.5
9	541	255	130	311	181	18.1

The table on this page will be of interest, as showing in condensed form the results obtained by economizers and mechanical draft in a number of plants in regular service. In nearly every case the feed water was partially heated by exhaust-steam heaters, or in hot wells by condensed steam from various sources.

THE RELATIONS BETWEEN GAS COMPANIES AND GAS CONSUMERS.

By Wm. Paul Gerhard, C. E.

NOT quite a century has passed since the birth of the gas industry, yet we already find gas light, in many instances, supplanted and displaced by the electric light. Even a casual observer cannot fail to notice the fact that the electric light is just now becoming "all the fashion," but does this mean that gas light is entirely doomed? Has not, on the contrary, the gas industry profited by the advent of the new light, and is it not a fact that the consumption of gas has increased in recent years instead of diminishing?

At the time when the electric light was first brought to public notice, Mr. W. H. Preece, in a lecture delivered in 1880 before the London Society of Arts, on "Recent Wonders of Light," uttered the following prophetic words: "Gas is a magnificent thing in itself, but one of the great advantages of gas has been that it has driven the candle makers and oil lamp manufacturers to give us hundred fold better things than they did before, and so the introduction of electricity, if it does nothing else, will compel our gas engineers to produce gas lighting apparatus as far superior to those of our youth as these ordinary lamps are to the oil lamps of the Greeks."

Gas lamps have taken the place of candles and oil lamps, and these same gas lamps are now in some cases replaced by electric arc and incandescent glow lamps, yet the older illuminant has in each case profited instead of suffering. Doubtless, one result of the improvements in methods of illumination has been a more lavish use of light, and the setting up of a higher standard in street as well as in domestic lighting. With the increased requirements, therefore, each kind of artificial light benefited by the advent of its successor, competitor and rival. The electric light, in particular, awakened the managers of the gas industry into activity, and a higher quality of gas at reduced cost, better gas fittings, more efficient gas burners and gas lamps have been produced, demonstrating to a greater extent than ever before the possibilities of the "light without a wick," created from "the spirit of coal." Gas lighting has been of incalculable benefit to mankind in the past; its many advantages are at present more than ever enjoyed in the household, in the office and in the workshop, and notwithstanding contrary statements by those interested in the development of the rival light, it is my belief that for a long time to come, gas will not only hold its own, but make still further progress. The coming century will, doubtless, be the age of electricity, but ours is the era of gas.

Having thus briefly glanced at the past, present and future of gas lighting, let us consider what shall be done to strengthen the future position of gas light in view of the rapid strides made by its chief rival, electricity. Every impartial observer cannot help admitting that the future of the gas industry must, to a great extent, depend upon the relations between gas companies and gas consumers. It is well known that these relations have not, in the

past, always been as pleasant as they might be. The bulk of the gas consuming public is lamentably indifferent or ignorant, or both, about the subject of gas lighting ; hence, the proper use of gas in the household is little understood. A few commendable instances excepted, gas companies have made no effort whatever to keep householders and gas consumers informed on the subject. Instead of trying to gain the consumer's confidence, many gas companies and their employees have persistently pursued the erroneous policy of surrounding themselves and everything pertaining to their business with an air of profound mystery. Worse than this, in many instances those employees of a gas company who come into closer contact with the public, often throw a veil of secrecy about the subject with a view only of hiding their own ignorance. All this is much to be deprecated, for as a natural result the consumer, already full of prejudices and dissatisfaction, becomes still more suspicious and biased. It would seem to me as if the best interests of gas companies demand that they enlighten the public, and that they help them in every way possible to consume the product of the gas works in the best manner.

Why gas companies should not make efforts to establish, or to maintain, pleasanter relations with their consumers has often been a matter of wonder to me. The interests of gas companies and gas consumers are mutual and should go hand in hand, therefore companies should constantly strive to dispel any bad feeling, to remove all prejudices and to avoid as far as possible all friction. The welfare of gas companies demands that they should not be indifferent to the wishes of the consumer. It is a fact capable of easy demonstration that where a company or its employees have taken the trouble to instruct the consumer how he can make the best possible use of gas, or how he can obtain a maximum amount of illumination from the burning of a given quantity of gas, an increased consumption of gas resulted for the company.

What then can gas companies do to bring about a better feeling between themselves and their consumers ? First of all, gas companies should attend to the complaints of the consumers. Nothing within the bounds of reason must be left undone to satisfy them and thereby retain or gain their confidence. By far the majority of complaints are first, about bad gas or deficient light, and second, about excessive gas bills. The latter are invariably attributed to the inaccuracy of the company's gas meters, or to errors of the clerks in making out the monthly gas bills, while the deficiency of light is usually laid to the bad or poor quality of the gas or to lack of pressure in the gas mains. Occasionally, consumers grumble about the flickering of lights, about hissing and noisy flames, about the breaking of gas globes, caused by gas flames with ragged edges, about the vitiated air, about immoderate heat and the injurious effects of gas lighting upon health and comfort, and about the destructive effects of gas upon the decorations, pictures, books and furniture, the walls and ceilings of rooms.

In some cases, no doubt, there is just ground for these complaints. The gas company should then endeavor to remove the causes, if practicable. But, as often as not, the complaints of consumers arise from their own lack of knowledge, or carelessness, or indifference. Very frequently, too, the troubles complained of are a result of the stupidity or cupidity of the gas fitter or the builder, and an impartial investigation would demonstrate that the complaints can easily be traced to one or more of the following defects, over which the gas company seldom has any control, viz., the use of gas piping of inadequate size, the improper running of gas pipes, the use of bad, cheap, or unsuitable burners, or to good burners having become obstructed or worn out ; to the use of ill-contrived and light obstructing brackets and chandeliers with tubing of insufficient size ; to the use of globes with narrow bottom opening made of light-obstructing material and supported by

heavy globe holders; or the failure of the gas light is due, in districts where a high gas pressure necessarily prevails, to the omission of pressure reducing appliances.

Consumers of gas should inquire into the subject of gas lighting without bias, and gas companies should endeavor to remove all manner of prejudices generally arising from ignorance or suspicion. Among misconceptions of consumers, the most difficult to deal with is the prejudice against the "lying gas meter." This is largely due to want of knowledge as to its construction and mode of operation. It is increased by the many stories of the vagaries of gas meters, disseminated by the daily press. Many consumers imagine that they are completely at the mercy of the gas meter, or that gas companies charge them whatever they see fit to charge. It is needless to say this is a great mistake. To remove this deeply rooted prejudice, gas companies should endeavor to teach the householder how to become familiar with the gas meter, and to encourage his frequent reading of the index, as many a serious misunderstanding may thereby be prevented.

As a matter of fact the size of a consumer's gas bill is dependent upon the quantity of gas consumed only and with this a gas company has little to do. As regards gas bills, wrong statements are rendered much less often than the average gas consumer supposes. The process of making out the bills is about as follows: Once a month the meter inspector calls at the consumers' houses, takes the reading of the meter, enters the date and the state of the meter in his record book, and returns the same to the gas company's office. Then the clerks in the office make out the bills by putting the last statement just taken at the top and the reading of the previous month under it. The latter amount is then deducted from the former, and the difference obtained is the last month's gas consumption. Errors of calculation can be prevented by checking the figures, and errors in the figures by a careful comparison of the previous and the present meter reading. Errors made in reading the meter are, as a rule, discovered at the end of the next month, it being then found that the consumer has either paid in advance or else too little, generally by an even 1000 cubic feet. By reading his own gas meter every month, or every week, or daily, a consumer has in his hands a perfect check against fraud or mistakes.

Again, a great deal of good might be accomplished if managers and officers of gas companies would endeavor to correct and dispel the numerous popular errors or fallacies regarding gas lighting. Among the more common fallacies I will mention the following:

a. That gas companies mix air with the gas to increase its volume. This admixture of air is never attempted, because it would obviously result in a serious deterioration of the illuminating power of gas, for even a 1 per cent. admixture of air reduces the candle power of gas by 6 per cent., and a 10 per cent. admixture reduces same by 67 per cent. Gas companies are required to make and furnish illuminating gas of a specific candle power, and the weekly tests of the gas examiners show that the quality of the gas rarely falls below this standard, as it certainly would if air were mixed with the gas. It is a fact, however, not so well known, that the quality of gas is variable with atmospheric changes. For instance, a fall in the barometer reduces the brilliancy of lighting by 5 per cent. for every inch of fall. According to Dr. Letheby, "in London, the difference in the value of the light when the barometer is 31 inches as compared with what it is at 28 inches is fully 25 per cent., and this, no doubt, accounts for many of the complaints of 'bad light' in November, when the barometer is usually very low." The quality of the light is likewise said to be variable with the amount of moisture in the air.

b. That gas companies blow or pump air from the works into the gas mains during the day to make the meter go around and to make the index register. This is sheer nonsense, for not only can the consumer at any

time by lighting a burner convince himself that the pipes contain illuminating gas and not air, but where no gas is burnt and the house pipes are tight, the consumer by watching the small index hand of the meter during the day will find that it remains stationary.

c. That large gas meters lead to an increase in the gas bills, and that large gas pipes in houses, as advocated by gas engineers, increase the consumption, and therefore the monthly gas bills, both of which beliefs, of course, are erroneous, as the gas consumption depends only upon the number and size of burners in use, and upon the gas pressure, but not upon the size of the conduit or pipe conveying the gas to the burner, and not upon the capacity of the instrument measuring the gas.

d. That the gas company willfully puts on more pressure at the works at night to make the gas meters in the consumers' dwellings go around faster. While the fact is true that the pressure is increased in the early part of the evening when a general lighting up begins, the gas company is obliged to do this to supply the distant consumers and those located in low level districts. The increased pressure causes increased leakage of gas at the joints of the street mains, and also leads to increased consumption at the street lamps with ungoverned burners, for which the companies, as a rule, receive a fixed annual sum by the municipality, hence it may be accepted without question that the gas companies would not increase the pressure if it were not necessary to do so.

e. That large burners lead to a waste of gas, and that where gas companies offer to put better, or larger burners on the fixtures of the consumer they do this not for the sake of giving a better light, but in order to increase the gas consumption. Careful observation shows that one large burner gives, with less consumption of gas, a better light than two small ones, which demonstrates the fallacy of the above misconception.

f. That gas vitiates the atmosphere more and creates more heat than either candles or oil lamps, whereas for the same amount of illumination the opposite is true.

g. That gaslight is more dangerous as regards accidents, such as fire, explosions, escape or leaks of gas causing asphyxia—than other illuminants, whereas the statistics of fire underwriters and the records of hospitals show more fires and accidents caused by lamp explosions, than by gas.

h. That if in one house, owing perhaps to insufficient size of the gas service or house pipes, the pressure is low and the light accordingly poor, the gas company is able to give to this consumer more pressure if he desires it than to the neighboring houses, which is obviously impossible.

i. That gas pipes may burst from the inside gas pressure, which mistaken idea possibly arose at the time when natural gas was first supplied to towns under sometimes very heavy pressure. With gas as supplied and distributed from gas works the pressure is, comparatively speaking, very light, fluctuating from $\frac{10}{10}$ to $\frac{40}{10}$ inch of water pressure, and there is not the slightest reason for fearing that the gas pipes may burst.

k. That inasmuch as the manufactured gas emits a strong and unpleasant odor, the same odor must exist and become disseminated in the rooms, when gas is burning. It is a fact, however, sufficiently well established by experience that properly purified gas, if properly burnt, gives off no obnoxious odors.

l. That gas may and does sometimes burn inside of the gas pipes. I have met well educated and otherwise intelligent people who displayed their utter ignorance on the subject by making such statements, thus reminding me of the people, in the early days of gas lighting, of whom we are told that they put on gloves before touching the gas pipes, and of the architects who required in their specifications gas pipes to be carried at a safe distance from all woodwork. The fact is, of course, that illuminating gas does not burn and will not inflame while confined in a

vessel or in pipes and fittings conveying the same, because air is necessary in all cases for combustion to take place.

m. That manufacturers of gas meters and gas companies work hand in hand to defraud the consumer, whereas the fact is that gas meters are measuring machines constructed with accuracy and on scientific principles, by responsible manufacturers, and that before use all meters are tested as to their accuracy by special State meter inspectors. Therefore, whenever a consumer believes his meter to be wrong, he may have it tested, exchanged, or repaired by notifying the gas company.

n. That gas bills are made out regardless of the amount of gas consumed, which popular error has been already alluded to in speaking of the prejudices of consumers.

Much can be done to remove such popular fallacies by proper explanations given to gas consumers. The gas companies have constant opportunities to give to their customers information and advice upon many of the matters touched upon above.

Still more good could be accomplished if gas companies would undertake to give direct advice and practical instruction on the details of domestic gas burning appliances. Some topics of interest and practical value to gas consumers are, to begin with, the gas meter, its construction and arrangement, with explanations of how to read the index of the same. If once the householder becomes familiar with reading the gas meter, misunderstandings or disputes about the gas bill would in the majority of cases be prevented. Then there is the gas piping of buildings. It has been said that a bad system of internal gas piping is the arch enemy of every gas undertaking, therefore gas companies should, in the case of all new buildings, see that architects, builders and gas fitters follow the best rules on gas piping. It would certainly lead to good results if gas companies would distribute rules and regulations on the best mode of doing gas piping, on the methods of running the distribution pipes, on the sizes of pipes, and the proper manner of testing gas pipes. Gas companies should in this way try to exercise some supervision over the consumers' fittings, and also insist upon the employment of responsible and qualified gas fitters only. Regarding gas burners, the gas companies should remind consumers that even the best of burners wear out and that worn out burners mean a waste of gas, also that burners become obstructed and need periodical cleaning. They might, with advantage, go a step further and give to the householder information regarding improved burners, or supply the consumer, either free or at a nominal charge, with the best kind of burners rather than see him at the mercy of the burner quack. Many consumers, without doubt, would welcome any judiciously thrown out hints about burners and lamps. Information about gas lamps and gas fixtures, gas globes, globe holders, shades and reflectors would also be useful, particularly a demonstration of the advantages arising to householders from the use of gas globes of clear glass with wide bottom openings, supported in shadowless triangles of thin wire.

Gas companies should explain the object and use of gas pressure regulators and of volumetric governor burners. In districts with excessive gas pressure they should teach the gas consumer the proper remedy for "blowing" burners. It is much to be regretted that, as a rule, gas companies are opposed to the use by consumers of pressure regulators of any kind, except the ordinary check burners which are notoriously unreliable, while they themselves make extended use of the best volumetric governor burners on their street lamps. The use of pressure regulators should be discouraged only where the house piping is quite insufficient in size. Much may be accomplished by employees of the gas companies giving instruction to consumers about the proper management and use of gas. Gas is wasted in houses in many ways, and children as well as

servants are proverbially careless or thoughtless in the use of gas, keeping lights burning many times when not wanted. Again, the householder's attention should be called to defective gas keys, such as the "all round" keys without stop pins, which often cause escapes of gas and may lead to serious accidents. There is not a gas consumer who would not thankfully accept advice upon such points, if it were given conscientiously and in a proper manner.

Many hints may be thrown out regarding the maintenance of gas fittings, the cleaning and renewal of burners, the cleaning of chimneys and globes, the greasing and tightening of the gas keys, the refilling of the water joint in hydraulic gasaliers, and kindred subjects. The annoying and aggravating irregularities sometimes occurring in the gas supply, and the proper way to remedy each trouble, should be lucidly explained. The consumer's attention should be called to objectionable gas leaks, whether in the pipes and fittings, or in the fixture joints, or at the gas keys, or at the burners, and the remedy given. All necessary and usual precautions against danger from fire should likewise be explained and commented upon. Useful hints may be given regarding the advantage, economy and convenience of gas cooking and gas heating appliances. The revenue of a gas company will be increased where the day use of gas is encouraged. In all these matters gas consumers must be aided and guided, and gas companies should not lose the opportunity of doing this, as the continued welfare of their business depends upon it. Many a grumbling consumer may be turned into a friend of the company by timely advice, given in a discreet manner. Gas managers, gas inspectors, and likewise all gas fitters should be well informed on these topics, so as to be able to give intelligent advice to the consumer.

While there are several ways in which gas companies may educate the consumers, one of the best means consists in the arrangement by the gas company, at their office, of a general exhibition of gas apparatus. In this exhibition should be included a collection of the best gas-lighting burners, also samples of governor burners, of well-shaped glass globes and shadowless globe holders, of improved modern regenerative and incandescent gas lamps, etc. A good gas pressure regulator should be shown in practical operation, likewise an exhibition meter constructed of glass, so as to show the interior construction and working mechanism of the gas meter. Finally, there should be exhibited the best examples of gas cooking ranges, of apparatus for heating water, for heating laundry irons, also gas heating stoves, incandescent fireplace heaters and terra cotta gas logs. All of these appliances should be fitted up with gas connections ready for lighting up, in order to show to the public their mode of operation, and their advantages and utility.

There can be no question that a well arranged showroom, containing a judiciously selected stock of the best domestic gas appliances, must have a powerful influence in popularizing the use of gas. Manufacturers of gas apparatus should aid the gas companies in this matter, as such a display would tend to create an increased demand for improved gas appliances. In connection with such exhibitions, popular lectures might be arranged on various subjects, such as on the use of gas for lighting, on cooking by gas, with demonstrations of practical cookery, on gas heating appliances, on gas motors, and the like. The gas exhibitions would prove a useful medium for distributing to consumers tracts or pamphlets upon the advantages of gas for light and fuel and power purposes and containing just such hints and general information as the public is most in need of. A liberal dissemination of such pamphlets must eventually result in a large reduction in the number of common complaints. It is likewise desirable that printed rules for gas piping in new buildings be circulated by gas companies amongst those who are chiefly interested, *i. e.*, architects, builders, plumbers, and gas fitters.

The question is often asked if it would not be advantageous to have the gas piping in new buildings done by the gas companies. After a careful consideration of this matter, I fail to see what material advantage, if any, could be derived therefrom. Gas companies necessarily must rely just as much as other contractors doing gas piping, upon the honesty, practical skill and ability of the mechanics, and in not a few instances have I found fully as much ignorance and carelessness among gas companies' fitters as among fitters in the employment of the trade. Whether the householder gives his gas piping work to the gas company or to a tradesman, a plumber or gas fitter,—his chance for securing perfect work lies mainly in paying a fair price for the work and insisting upon the employment of only competent fitters. Here, as elsewhere, the best results may be secured by proper expert supervision.

Not a little of the ill-feeling existing between gas companies and gas consumers is due to the disrespectful treatment which consumers' occasionally receive in some gas offices. Employees of gas companies, and in particular the inspectors of gas meters and those clerks in the office, who come into more frequent contact with the public, should be required to be courteous and polite in manner and speech. After all, the public have a right to demand at least the same fair treatment in a gas office which they receive by clerks or salesmen in stores in which they make the purchases of the sundry necessaries of life, and where, as a rule, they are shown that they are valued customers. Fully aware of the fact that the position of the clerks in the gas office, who receive the consumers' complaints, must often be a very trying one, I still hold that the ill-temper of the clerk should never be vented upon an unoffending customer. Here, as in other lines of business, it pays to be patient, obliging and polite, and nothing is gained by showing even the slightest sign of irascibility. Customers, on the other hand, ought to bear in mind that very often the clerks and inspectors of gas companies are abused by the suspicious, the ignorant, the ill-mannered people, necessarily forming a portion of the customers of a gas company, and they should therefore condone a clerk's offense of sometimes appearing gruff, impatient and uncivil.

In short, gas companies would undoubtedly be on better terms with consumers if they had not, in too many cases, disregarded their wishes. The enlightenment of the gas consumer is of importance, for even well-educated men often display a very deplorable ignorance and bias as regards the use of gas. Then the public should be taught that a gas company's business is legitimate and that their dealings are just as honest and upright as the transactions of other business concerns. And, lastly, consumers who go to the gas company's office for advice should have confidence in the suggestions made by the company. A proper observance of what has been herein stated, would undoubtedly pave the way toward better relations between gas companies and gas consumers.

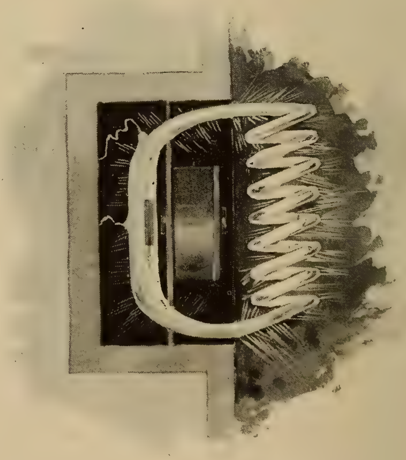
THE LIGHT OF THE FUTURE.

By D. McFarlan Moore, Mem. Am. Inst. El. Engrs.

LIGHT is popularly considered as a something that is almost intangible, and the idea of conveying or forcing it through tubes or pipes, in a manner exactly similar to that in which we now distribute gas or water, is strikingly novel. When gas was first introduced, about seventy years ago, there was a popular idea that the light extended throughout the interior of the gas pipe; but a similar idea may not be erroneous in connection with the light of the future. Can light be so carried, and how? may well be asked. Although a radical departure, and one not heretofore proposed, it is not unlikely that the near future will witness the commercial adoption of the transmission of light through tubes, and that it will be accomplished by the utilization of the great modern agent, electricity.

Nature's laws seem to prohibit much further advancement in bettering our present means of transforming heat into power, and power into electric current, but this does not hold true when we consider the third step,—converting electricity into light. The incandescent electric lamp of to-day hardly satisfies the demand of these progressive times, and a new method must succeed it. Light, however, will still be produced from electricity which, from its inherent merits, will eventually entirely supersede all other means of illumination. A few years hence artificial light will probably be so abundant that the business and social world need suffer no inconvenience whatever from the invasion of night, and will practically enjoy continuous daylight. Then, reminiscences of oil and gas will be as curious as those of candles are to-day.

The incandescent lamp is preëminently the modern means of illumination. This has been demonstrated, in a measure, by the unparalleled rapidity of its introduction. Still, it is far from being perfect, and does not by any means fulfill the requirements of an ideal illuminant. Withal, its invention was the greatest step toward ideal illumination ever accomplished, and



A WALL POCKET GLOW LIGHT.

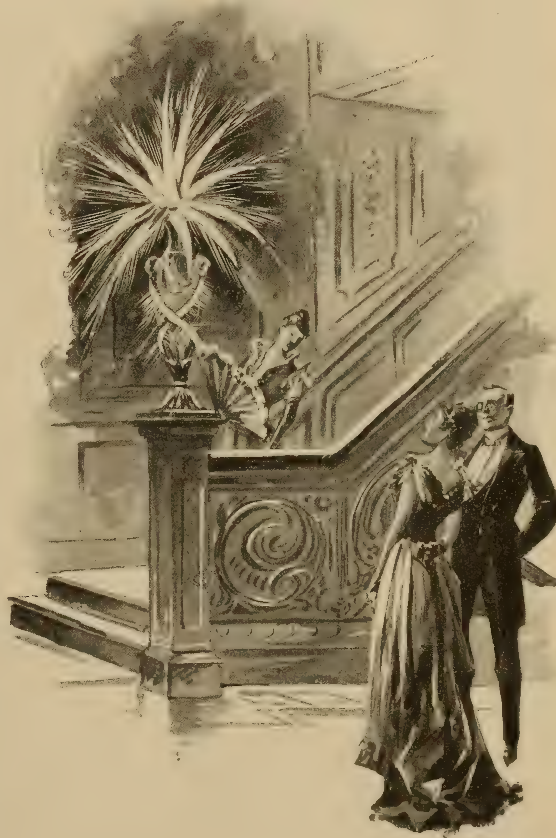
almost all the objectionable features of the various methods of lighting previously employed are absent from it. Most prominent among the drawbacks which had hitherto baffled science were flame, odor, heat, and consumption of oxygen. But the incandescent lamp does not afford a means for producing maximum uniformity in the distribution of light, nor is it efficient. Modern progress is looking for light without heat, or, at least, with much less than

now seems unavoidable. Incandescent lighting is the pride of advanced science and it is often described in a roseate manner ; but it is sad for the economist, or one who is deeply interested in the conservation of energy, to reflect that only five per cent. of the energy of coal is converted into light by this system.

The ultimatum of idealism in the matter of light would be the discovery of a commercial means of storing up daylight, but since the efficiency of the modern dynamo is almost ideal, the most hopeful solution of the problem is in the direction of an economical method oftransforming electricity into light. As currents of electricity can be efficiently converted into power, why should they not be efficiently converted into light? The incandescent lamp, at present, heads the list of artificial illuminants. It produces more light and less heat than any other method of dispelling darkness. It radiates comparatively little heat on its surroundings, but, still, its very name defines its character. It represents simply concentrated heat. The actual amount of heat present, however, is not very great. The radiating surface is reduced to what seemed to be a minimum, and was a minimum for the times.

It may be asked, why not complete the subjugation, by still further reducing the radiating surface? This, however, would seem impossible, since the high resistance necessary requires a length of filament varying directly with its diameter, and we seem to have reached the limit in producing commercial filaments of small diameter. A means for removing this difficulty and making use of a minimum concentration of heat, should be sought, and means other than a filament of high resistance should be provided to obtain from the electric arc a more desirable light, and one of a radically different quality, than that produced by either the present arc or incandescent lamp. This ideal light should not only retain, but add to, the wonderful advantages of the present lamp.

There is no question as to the almost unlimited value of phosphorescent or glow lighting when reduced to a commercial basis. Many attempts have been made to obtain this light, but a new and fundamental principle is herein



A STAIRCASE EFFECT.

suggested which differs from any other principles heretofore tried or proposed. Electric sparks rapidly succeeding one another in a vacuum are the key to the whole system. One method of producing such sparks with a minimum amount of mechanism within an attenuated atmosphere in a bulb, is shown in the sketch on page 239. A small piece of soft iron is supported by a plati-

NOW.

num wire which is connected with one end of the wire of an electro-magnet. The other end is connected with one pole of the source of current supply. The wire from the other end of the glass bulb is connected to the other pole. The connections being made, the small piece of iron, or armature, will commence to vibrate rapidly, and every vibration will break the current at *a* and produce a spark. These sparks will agitate the ether in the bulb and cause the entire bulb to give forth light, or, to express the action more scientifically, the current will be rapidly disrupted by a magnetic field exterior to the evacuated space. If the potential is comparatively high, the armature may be eliminated and the sparking varied by means of an exterior magnetic blast.

Light, like other forms of energy, is due to vibrations, and this statement introduces one to the realm of molecular physics, the hope of the future. The problem of light generation, therefore, resolves itself into the production of extremely rapid molecular vibrations. This can be accomplished by the utilization of electric currents in the manner just described, and the amount of light, or luminous energy, thus obtained will be the maximum obtainable from a given amount of electric energy. No electric current can be broken without producing extremely rapid oscillations, that is, it cannot be broken instantaneously. The fact that the entire bulb glows, demonstrates that the oscillations occurring in disrupting ordinary commercial currents are sufficiently rapid to produce light in an atmosphere attenuated to a proper degree, that is, under conditions where the molecules can act most freely. To effect this, the molecular rigidity must be exactly suit-

IN THE FUTURE.

able ; in other words, there must be neither too few nor too many molecules in a given space. When a low potential current is used, the self induction upon its rupture produces the high tension necessary to molecular vibrations of sufficient frequency to cause luminosity. The exceedingly rapid succession of disruptions occurring with a single break of the circuit are also due to the fundamental law that a perfect surface does not exist. The two most perfect surfaces obtainable, when used as contacts, touch each other at an infinite number of points. The electric current is a molecular motion of a certain rate of vibration, and, therefore, every molecule in a contact is so vibrating that when the current is broken it is, in molecular reality, broken at innumerable points, each one of which sets into motion the ether molecule in contact with it. The result is molecular light. The impulsive rush of electricity on the rupture of a current seems to set the ether into electro-magnetic undulations, similar to heat waves, but of much shorter length, and they therefore constitute light. A disruptive discharge is oscillatory, owing to the variation in the conductivity and density of the surrounding atmosphere. The entire bulb gives forth light, because the vigorous action of the molecules nearest the arc sets into motion other molecules with which they come in contact, and thus they act and react upon each other and the enclosing chamber. The luminosity will vary in intensity and color in accordance with the medium in which the discharge occurs. Of course, the intensity is a function of the rate, and number, of different discharges or contacts per unit of time.

Phosphorescent electric light, in the past, has been produced by using alternating currents of extremely high tension and frequency, but this method is neither economical nor practical. Furthermore, it is not expedient to use currents so difficult, dangerous and expensive of generation and manipulation as to prohibit their use commercially, when the same results can be obtained by using ordinary commercial currents. The salient difference between phosphorescent electric and incandescent electric lighting is, that in the former the entire bulb glows or emits light, while in the latter, the light is confined to a slender filament, and the size of the bulb has nothing whatever to do with the quantity and distribution of light. In the system of phosphorescent lighting proposed, the molecular action and consequent light is most intense where generated, that is, in proximity to the electrodes or contacts ; but it soon travels throughout the confines of the enclosed space. The illustration on page 236 shows a beautiful spiral of light, together with its method of generation, designed to take the place of a wall bracket, the pocket being concealed in the panels of

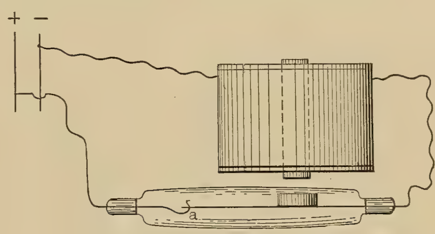
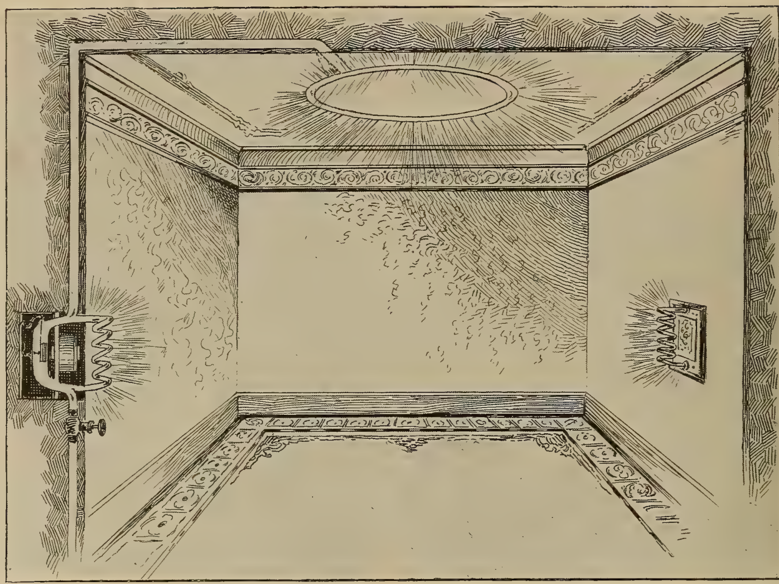


DIAGRAM OF SPARK PRODUCER.

the woodwork. Branches can be extended from this enclosing chamber near the source of light generation, enabling distribution of the light in a most ready and simple manner.

A case is shown on the next page, where the light, generated in a pocket in the side of a room, emits its rays in the form of a circle of light, the transparent termination of the air-tight tube. Although light will travel of its own accord through a tube, its progress may be made more rapid by the use of magnets, forcing or drawing light to the remotest ramifications of air-tight tubes. These can be made transparent whenever desired, and shaped as fancy or taste will dictate. The phenomenon that light, so generated, can be conveyed within a proper medium, until its remotest portions are lustrous, suggested this radical departure. Such light might well be called etheric light,



WALL POCKET AND CEILING TUBE ILLUMINATION.

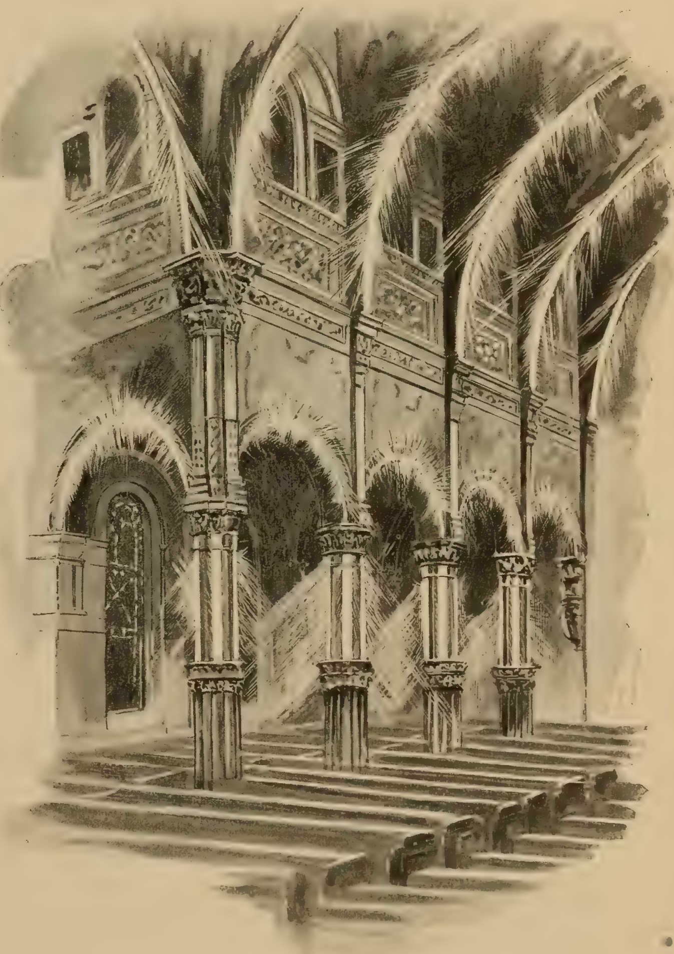
as it is produced by vibrations of the ether. This light fulfills all the requirements of ideal specifications. It is the most efficient light, because it is most equally distributed, and its artistic possibilities are of the very highest order. The great problem of the subdivision of the electric light barred, for many years, the advent of commercial incandescent lighting. Edison was ridiculed in France and in England when he first claimed a solution. Davy's first electric lamp, made in 1808, contained all the essential elements of the lamp of to-day, but it needed refinement,—commercial refinement. The fruits of the invention of the subdivision of the electric light, rendering possible the production of small units of light, are still ripening. Commercial refinement demands still greater subdivision, and small units of light are becoming a positive necessity for the purposes of ornamentation and economy, furnishing beauty and brilliancy without glare. Miniature lamps of low candle power are already being generally adopted for interior lighting, clearly showing that the tendency is in the direction of securing a more even distribution. This could be most perfectly accomplished by phosphorescent lighting. Long continuous tubes, of every conceivable shape, emitting mellow light in every portion, may soon supersede the small separate bulb, containing a painfully brilliant filament, the length of which it has been found impossible to increase for decorative effects. Various designs in incandescent electric lighting are now constructed by properly arranging numerous incandescent lights in the forms desired ; but with phosphorescent lighting the light of all of the lamps would, as it were, be merged into one harmonious whole.

All present methods of lighting tend toward the production of an increased number of light units of steadily decreasing candle power. Powerful arc lamps, closely grouped and placed on tall poles, represent a system of the past. What is required is a maximum radiation from a source of considerable area. We want light,—not lights ! Phosphorescent electric lighting most closely resembles daylight, and gives no sharply defined shadows. It is safe and can be controlled at a distance.

In the lighting of buildings, two gen-

eral methods of utilizing phosphorescent electric light, generated as described, suggest themselves,—one with wires, and one without wires. In the first, wires will conduct electricity to wall pockets where it will be converted into phosphorescent light, and in the second, all the light will be generated in the basement of a building and conveyed to the desired points by a system of air-tight tubes. Where feed wires are used, and it is desired to extinguish the light, the current is merely shut off by means of an ordinary switch. In the second case, air-tight cocks would be used in the tube system. From the earliest times the underlying principle of all artificial illumination has been to make the light ornamental as well as useful; but even with electricity this has been thwarted by the objectionable incandescent filaments. The most greatly admired examples of decorative lighting, in which the incandescent light is treated as an æsthetic element, demonstrate most forcibly that its cheerfulness, purity, and softness are highly appreciated, but that the glare of the filaments must be subdued, and the filaments themselves never exposed to view. With phosphorescent lighting no lamp renewals will be necessary, there will be no filaments to burn out, no struggle to conceal dazzling loops. Illuminative art will have a free rein, and effects, almost undreamed of now, will be of easy accomplishment. The coming cylinders of light will glow with impunity in the open. There will be nothing objectionable needing concealment, and, should they be hidden behind screening cornices, they will cast their soft light upon the ceiling, and reflected rays, in turn, will be diffused through space.

When electricity was introduced for lighting purposes, gas chandeliers were soon transformed into electroliers, and exquisite designs in metal, for a fitting display of the lamps, were brought out in endless array. But, in the future, elaborate fixtures will be conspicuously absent. The new light will be so perfect that to seek enhancement of its beauty by such investments will be fruitless. The much-admired lighting of recently constructed halls, theatres,



A CHURCH INTERIOR WITH THE NEW LIGHT.

A DRAWING-ROOM OF THE FUTURE.

and churches, in which the entire ceilings serve as fixtures, proves that already the pretentious electrolier is neither imperative nor desirable. Paintings on translucent materials are already popular and suggestively point to the eventual lighting of rooms through their pictures, with glowing bulbs and tubes behind. Since the principle has been discovered upon which such possibilities may depend, it is, indeed, to be hoped that the new field will not remain neglected, and that what here partakes of the nature of suggestions will soon become assured accomplishments.

J. STEPHEN JEANS.

By George Cawley, Mem. Inst. M. E.

IF there is one thing more than another upon which Englishmen have good cause to plume themselves, and in reference to which they have, until recently at all events, enjoyed an unsurpassed prestige, it has been their pre-eminent place among the industrial nations of the world. That pre-eminence has largely been due to the command which England acquired in advance of other nations of a cheap and abundant supply of the useful metals, and especially of iron and steel. Dudley, Darby, Cort, Rogers, Heath, Bessemer, Siemens, Mushet, and other names crop up in rank luxuriance, when we look back upon the history of the English iron trade, and these men, with the energy and ability characteristic of the race, placed and retained England on a high pedestal of industrial power and prosperity, until she was dethroned by the superior resources of the United States.

During the past seventeen years or so, few names have been better known in connection with the iron and steel industries of Great Britain than that of Mr. J. Stephen Jeans, who has acted as secretary to that important branch of technology and of trade in a double capacity, namely, first, as secretary to the Iron and Steel Institute, and, second, as secretary to the British Iron Trade Association. The former of these organizations, as is well known, was the first general association established to represent the technological aspects of the iron industry. It was founded in 1869, and Mr. Jeans became the secretary in 1877, continuing to hold the office until he resigned in 1893. The other association, which represents the commercial and industrial interests of the British iron trade, as such, was founded in 1876, and Mr. Jeans has continued to hold the office until the present time. This period has witnessed very remarkable changes in the iron industry, both from a technical and from an industrial point of view. The Bessemer and Siemens steel-making processes have been developed from comparatively insignificant to colossal proportions in most of the steel-producing countries of the world. The United States have taken up the premier place among steel-producing countries, leaving Great Britain in a second place, first in the manufacture of steel, next in the manufacture of pig iron and in the production of iron ore, and finally in the production of coal. But amid all the chances and changes which this movement has involved, the Iron and Steel Institute, with Mr. Jeans at the secretarial helm, has held a foremost place, and has been recognized in all iron-producing countries as the parent of general metallurgical institutions. It has been that gentleman's duty, as the secretary, to organize meetings of the Institute in Germany, Austria, Hungary, France, and the United States, and most American engineers will be able to recall the very successful series of meetings that were held in the last-named country in 1889, when some four hundred members of the Institute assembled from all the chief iron-producing countries of the world, first at New York, and afterward at Pittsburgh, to discuss papers of great technical importance, and to partake of that hospitality which Americans know so well how to dispense to honored and acceptable guests.

During those seventeen years, the Iron and Steel Institute more than doubled its membership, and much more than quadrupled its influence. It has attracted to its ranks the leading metallurgists of all countries, and it has, by its peripatetic movements, and by

the assiduity with which it has cultivated papers on foreign metallurgy, received a recognition among foreign men of science that few other institutions of the kind can claim. The blue ribbon of the metallurgical world is the presidency of the Institute, which has been held by many distinguished men, including the late Duke of Devonshire, the late Sir William Siemens, Sir Henry Bessemer,—happily still left to us in a hale old age,—Sir Lowthian Bell, Sir Frederick Abel, and others.

The British Iron Trade Association is an organization that corresponds to the American Iron and Steel Association, just as the Iron and Steel Institute corresponds to the American Institute of Mining Engineers, although the latter is entitled to claim a wider scope than its prototype in England. It has, however, this strongly-marked difference of character, that whereas the primary function of the American Iron and Steel Association appears to be the maintenance of the tariff, the corresponding function of the British Iron Trade Association is to break down the tariff, as far as its influence can be made to reach, and to establish the economic system of England instead. In one other, and perhaps the next most important function of the two organizations,—that of the collection and publication of statistical and other information of interest or importance to the trade in its commercial aspects,—the two associations are much more nearly akin. Both have for a number of years disseminated among their members such data, collected with much care and labor, and universally recognized as the referendum to which all inquirers for statistical information must appeal.

But Mr. Jeans is likely to be known to a large circle in the United States in another or, rather, in other capacities than the one just indicated. He has for many years been a prolific writer on industrial and economic subjects, and as such he has been at different times quoted both in the American Congress and in the British House of Commons. When the Republican leader made his trenchant speech against the Wilson Tariff Bill on the first of February last, he repeatedly quoted Mr. Jeans as authority for statements that he put forward, referring more especially to a paper on the American tariff, communicated by that gentleman to The Fortnightly Review, a leading English monthly, of December, 1892. When Lord Randolph Churchill, some years ago, made his vigorous attack in the House of Commons on the Indian policy of the British Government, he appealed to Mr. Jeans as the authority for many of his facts and figures; and when, on a more recent occasion,—on the tenth of November last,—Mr. John Burns, the labor leader, made his great speech in the House of Commons, against the contracting-out clause of the Employer's Liability Bill, he also quoted many of the facts which he submitted from a paper on the subject that had been presented by Mr. Jeans at an important meeting of employers. On this latter occasion an episode occurred which may be of some little interest to Americans. Mr. Burns had gone out of his way to denounce Mr. Andrew Carnegie as "the worst employer of labor in the United States," referring, of course, to the incident of the unfortunate Homestead strike. Mr. Jeans, having occasion to reply to some other remarks made by Mr. Burns in the same speech, took the opportunity of saying, in a letter to The Times of November 13th last, that the later course of events in the United States, from an industrial point of view, had fully justified the action of Mr. Carnegie and his partners, in seeking relief in the matter of wages, and that Mr. Carnegie's large experience and prescience had enabled him to discern the coming events that were then casting their shadows before. We have unhappily had still further confirmation of the same circumstances, in the depression of trade and industry that has continued to prevail up to the present time.

As an economist Mr. Jeans has for many years taken a leading part in the affairs and deliberations of the Royal Statistical Society, and sat, for some six or seven years, as a member of its

Council. Among the papers which he has read before this Society, two are of special interest in view of the present unsettled and disturbing condition of the labor question in all the principal nations of the world,—the first on "The Comparative Efficiency and Earnings of Labor in Different Countries," and the second on "The Recent Movements of Labor in Different Countries, in Reference to Earnings, Hours of Work, and Efficiency." The former paper, Mr. Jeans subsequently developed into a considerable volume, under the title of "England's Supremacy, Its Sources, Economics, and Dangers," which has been republished by Harper's of New York, and translated into several European languages.

Among the other works which Mr. Jeans has published from time to time, special mention may be made of his "Jubilee Memorial of the Railway System," a book written in 1875 under instructions from the directors of the Northeastern Railway Company, one of the largest railway corporations in England. On the occasion of the celebration of the Railway Jubilee at Darlington, in September, 1885, the directors of the Northeastern Railway Company gave a grand banquet to 1000 guests from all parts of the world, when a copy of Mr. Jeans' book was presented to each guest. Then there are his well-known books on "The History, Properties, and Manufacture of Steel," which has had a large circulation in the United States; a work on "Railway Problems," which deals largely with American railways; another on "Waterways and Water Transport," which reviews the developments and present situation of the American canal system; and more recent works on "Rings, Trusts, and Corners," published as one of Methuen's Social Science series; on "The Eight Hours' Day," and on "Industrial Conciliation,"—three subjects which he has made almost as much his own, as he has the technology, history, and statistics of the iron and steel industries. When it is added that Mr. Jeans has read numerous papers before the Society of Arts, the East Indian Association, the Iron and Steel Institute, the Cleveland Institution of Engineers, the Institute of Secretaries, the Royal Statistical Society, and other bodies, it will be evident that whatever else he may have done or left undone, he has at any rate been a diligent student and a hard worker in this important field.

Having had occasion during and previous to his secretarial career to lament the want of a publication that would give a general idea of what the technologists and engineers of different countries were doing in their different spheres of action, and which would consequently keep the different industrial countries abreast of each other in the knowledge and application of technical advances, Mr. Jeans, a little more than a year ago, made arrangements for the publication of a high-class monthly journal, which should be a Review of Reviews, in technical journalism. Hence, The Engineering Review, of which he is now the editor, and which attempts the difficult and hitherto untried task of making a *précis* of the technical press throughout the world. The attempt is a bold and an ambitious one, but it has met with a large amount of encouragement and success, and there can be little doubt that it will be found of great advantage to the engineering world, by bringing home to engineers in different branches of work, and in all countries, a knowledge of the best things that are being done or attempted in each. Something like a hundred and fifty journals are examined and abstracted for the purposes of this monthly *précis*, which is published under the heading of "Digest of Current Engineering Literature." In addition to this, the most prominent feature of his unique journal, Mr. Jeans presents an alphabetical subject index to the current engineering literature of the day, which gives his readers a clue to other articles that may not be deemed sufficiently notable to deserve an abstract. It is only proper to add that some features of the same undertaking have been attempted, although

on a much smaller scale in several American publications.

For this enterprise Mr. Jeans had, no doubt, been specially qualified by his previous training. He was trained as a journalist, having been the editor of a daily journal, published in Glasgow, proudly termed by Scotchmen the "Second City in the Empire," at twenty-three; having, at the age of thirty-one, become secretary to a leading technical society already named, and having acted as editor of its proceedings for a period of sixteen years. Mr. Jeans is a member of several of the learned societies, as well as a more or less regular contributor to The Times, The Nineteenth Century, The Fortnightly Review, and other English publications of the first rank.

AN INTRODUCTION TO THE ENGINEER.

By H. M. Norris, Jr. Am. Soc. M. E.

"IN the beginning God created the Heaven and the Earth," endowing the earth with natural forces constrained by fixed laws. The after creation of man brought into the world the engineer, who, by a constantly increasing appreciation of nature's absolute laws, has converted these forces to practical utilitarian account, thereby raising man from the infantile and semi-savage state in which unaided nature would have left him, to the present state of civilization and intellectual refinement.

How little is generally known of that vast army of men, of which every member is entitled, to a greater or less degree, to the title of engineer. Few there are, outside of those immediately interested, who at all understand the meaning of the term, and fewer still, even of those best informed in the affairs of the world, who have a true conception of what civilization would be without him. Is there no way in which it may be made clearer to the people what the engineer is, and what he must needs be to be fitted for, and capable of, guiding, constraining and utilizing the powers of nature? He is pre-eminently a man of thought, one possessing the power of quantitative reasoning, clear perceptive faculties, broad intellect, unlimited patience and intuitive promptness of action. The development of these traits, some natural, some acquired, tends not only to elevate his own profession, but to hasten onward the march of civilization to a far greater extent than the work accomplished in any other profession. The engineering faculty is in some degree inherent with all men as it was with Adam when he made for himself a girdle of fig leaves; and wherever natural materials are put to constructive uses, this faculty is brought into play; but in the professional engineer the development and training of this instinct is specialized and becomes his life's work.

How few realize to what a great extent the majority of other professions and occupations are based upon the inventions and creations of the engineer, and what an all-powerful factor he is and always has been in the progress of civilization. What would become of the writers and publishers of to-day if there were no printing press,—the greatest civilizing machine the world has ever known; of the lawyer, if he had no books from which to draw his knowledge and which are ever his advisers and teachers; of the surgeon, who without his knife and needle would be little better than the Indian medicine man; or of the dentist, who would be reduced to pulling teeth with a bit of carpet string? What if there were no electricity, rendered available by engineers, to convey our messages across

the seas, or to enable us, through the telephone, to converse with those thousands of miles distant, and by means of its light to turn night into day?

Think of the many engineers who, by the development of a single thought, have invented machines for the manufacture of which huge mills have been built, giving employment to hundreds,—it may be thousands,—of hands, who, settling in close proximity to their work, have formed the nucleus of a town, a city or a great commercial centre. What other professions do this? In what way would we be superior to the Central African negro if we had no steamships or sailing vessels of any kind, no railroads, canals or bridges, no looms, no spinning or sewing machinery, no agricultural implements, no knives, forks or spoons; or if we had no needles,—such little things,—and yet requiring, even with the most modern machinery, so much skill in the manufacture, each one passing through twenty-two processes before completion, and three millions of which are consumed daily? It is indeed these very inventions of the engineer which have enabled him to chain together, as one great power, tending toward greater civilization, all the nations of the world. How vast a field ot thought and knowledge he has also opened to us by the production of the mighty telescopes of to-day, enabling us to look at the moon as though it were but a mile distant, and read from the heavenly bodies lessons of great value to scientists; and yet in the face of all this, and remembering, too, that without the aid of the engineer, America could never have been discovered, the question, "What is an engineer?" would remain unanswered by about nine people out of every ten. When a man decides that his son is to be a lawyer, doctor, artist or editor, or that he will enter the army or navy, it is very clearly understood what the future of that young man is likely to be; but if he says that his son is to be an engineer, it means very little to the average listener. If the artist, doctor or clergyman who had just crossed the Atlantic were asked, "What is an engineer?" he would probably answer, "The chief of the engine room." Ask one of these after he has crossed the States, and he will say it is the driver of the locomotive; ask the man whose son is a draughtsman, he will tell you that his son is an engineer; ask others, and some will say that it is the man who builds bridges and railroads; others will have a vague idea that a great many men are called engineers, for they remember that when a canal is constructed, a mine sunk, a reservoir made, or an electric railroad built, there is always one who is called the engineer of the undertaking. There are few, however, who understand the full significance of the term, the majority not separating the engineer from the engine driver, mechanic or other iron worker, who is merely the engineer's assistant. They see a man in overalls, begrimed with oil and dirt, and are told that he is an engineer. When, therefore, a college graduate says that he is an engineer, they connect him at once with the engine room man, or think of him as a hand toiler at a class of work which is merely a preliminary part of his training, and never take into account the profound study which is necessary to obtain this proud title.

What would the professional status or social standing of the doctor, architect, lawyer or artist become were we to give the same title, respectively, to the chemist's assistant, the hod carrier, or the color mixer? Whoever heard of calling a chemist's assistant a doctor, or stone mason an architect? And yet an analogous misnomer is applied every day to those men who either use or assist in the mere manufacture of what has been conceived and designed by the brain of the engineer. If the coal heaver be called a fireman and the man who puts on brakes be called a brakeman, why should not the engine driver be called by the similar term of engine man and let alone the term which is a title belonging strictly to the professional engineer?

The engineer, is, more often than not,

hidden behind the results which have been made possible by his agency alone. It is, thus, the productions, rather than the productive machinery, which obtain the praise of the people. Paderewski is listened to with delight; he is pronounced a marvel, a genius; but his instrument, the piano, is unnoticed. A beautiful piece of dress material is greatly admired, but no one cares how it was made. A surgeon gains renown by some new and successful operation, but no one asks who made the delicate instruments used. Doctor Koch asserted that he had discovered the specific germs of consumption, and all the world did him homage, but no mention was made of the wonderful apparatus, by means of which this discovery was made possible. The daily papers, illustrated with wood-cuts of yesterday's events, are looked at by the million, but they give no thought as to how such things can be produced so quickly.

One reason why so little is known of the engineer is that the nature of his work is such that it seldom connects him in a close or sympathetic manner with the people, and so, unlike doctor or lawyer, his work is not brought home to their minds. His writings, as well as the results of his scientific researches, are rarely published or even spoken of outside of the technical journals. The chief reason, however, why the public fail to comprehend what specific kind of work the engineer does is that, unlike the terms used in the medical profession, the titles mechanical, civil, naval, mining and electrical engineer are used in too broad a sense and cover too vast a field to be readily understood. If we speak of an oculist it is at once understood that we mean a doctor who has made a special study of the eyes; if we speak of the dentist, it is understood we mean one who has made a special study of the teeth. And so it is with the law. The criminal lawyer defends criminals; the patent lawyer looks after patents, and that branch of the law relating to the navy and all shipping is called the admiralty, the nomenclature in each case pointing out the particular branch of the profession followed. The terms naval, mining, and electrical engineer do also, in a measure, specify a particular branch, but each of these branches is subdivided into so many other specialties that it is impossible to gain a clear conception of what a man actually does if he simply tells one that he is a naval, mining or electrical engineer, and when he says that he is a mechanical engineer he conveys no idea whatsoever. There is in the title nothing to indicate to the public whether he has made a special study of the locomotive, designs intricate machine tools, or superintends the manufacture of women's hair pins.

WIRE ROD ROLLING.

By Robert W. Hunt, M. Am. Soc. M. E.

LECTURING on wire rod rolling several years ago at Sibley College, the writer presented substantially what is given in the following pages, having, however, revised the present paper and added to it so that it correctly reflelts current practice. Wire rods quite naturally at once suggest the product made from them, or wire itself. Wire rods are an intermediate product, representing an important step between the crude material and its higher development. It may prove interesting to briefly summarize the history of wire and the development of its manufacture. A work entitled, "A Treatise upon Wire, Its Manufacture and Uses, etc.," by J. Bucknell Smith, C. E., of England, will be found valuable to any who desire to more fully study this subject. I am indebted to it for some of my dates and other particulars.

The manufacture of wire is of very ancient origin. It has been traced back to the earliest Egyptian history. Specimens are in existence which can be proven to date to 1700 B. C. The Kensington Museum has a specimen which was made in Minera, 800 years B. C. Ancient literature contains many references to wire. From the ruins of Herculaneum, metal heads have been exhumed on which the hair is represented by wire. There is no question that this ancient wire was made by hammering out the metal, which was always bronze or of the precious group. This held true of all made previous to the fourteenth century, during which the process of forming wire by drawing or elongating the metal by forcing it through a conical orifice, made in some substance harder than the metal treated, was invented. It is not until this time that we have any evidence of iron having been used. At first this drawing was by hand power, and it continued so until the latter half of the century, when a German, named Rudolf, built some kind of a power mill in Nuremburg. About 1500 this industry was introduced in France by one Richard Archal. A half century later, Queen Elizabeth, of England, granted permission to some Saxons to establish power wire-drawing in her domains. Their first mill was driven by water power, and was located at Holywell. But for some time before this, hand drawn wire had been made in England. Pre-American ideas seem to have belonged to the business, as in 1630 Charles I., by royal proclamation, prohibited further importation of wire, because the home supply was sufficient both in quantity and quality. This must have given some encouragement to the "infant industry," as we are told that thirty-three years later the first really mechanical wire mill was built in England, at Sheen. Protected inventive genius had asserted itself. Germany had been the first to develop power drawing, and did not remain idle. In fact, that country, Belgium and England have practically been the only European nations in which the wire industry has flourished. For years after its introduction into this country we depended upon them for our main supply of both billets and rods.

Before entering upon the consideration of rod mills, I will further follow the reduction of the rods themselves into wire. The rod is received by the wire drawer in the form of a coil, the rod being of varying section and the coil of a weight depending upon the purpose for which it is intended. One end of the rod is pointed and somewhat reduced by machinery. The coil is then given a bath in mild acid to remove all oxidation, afterward washed in lime water to

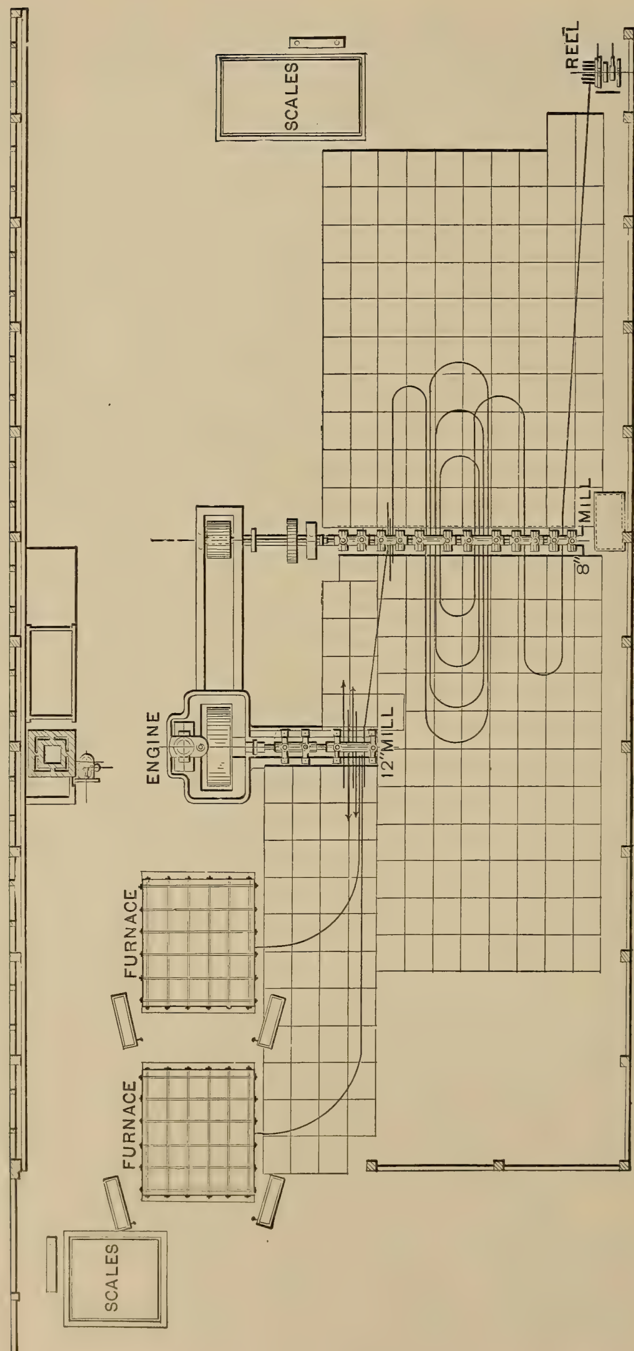
THE GARRETT ROD MILL OF THE ILLINOIS STEEL COMPANY, JOLIET, ILL.

give a drawing surface, and is finally dried in a proper oven. When ready for drawing, the pointed rod is inserted in one of the holes of a drawing plate. This plate is generally of steel, but some factories use cast-iron. The drawing holes are conical and the rod is inserted from the larger end. On the other side of the plate the pointed end is seized by power pincers and pulled until enough has been drawn through to allow of its being passed around and fastened to a drum or reel which is driven by power. Of course the rod is reduced in area and much elongated, and this without any perceptible loss of metal. While passing through the plate it is kept lubricated with what is called wire drawers' soap or grease. After being drawn through this first hole it is put through a series of smaller ones until it has been brought down to the requisite size. But the compression and disturbance of the structure of the rod consequent upon these reductions has hardened it so much that at certain stages it is necessary to stop the process and soften the metal by annealing. After this, it is again washed in acid, etc., and the drawing is resumed. Iron and the harder grades of steel require five or six annealings while being reduced to the finer gauges of wire. But the manufacture of soft steel and the details of rolling it into rods have been so perfected, that soft steel rods can now be drawn into fence wire without any cleaning or annealing. After the final drawing the wire is finished in various ways, depending upon the purposes for which it is intended.

No matter of what metal the wire may be composed, the same general system of drawing is used, varying more or less according to the metal. Including gold, silver, platinum, copper, etc., the commercial sizes of wire run from $\frac{1}{4}''$ to $\frac{1}{7000}''$ in diameter. The human hair is given as averaging $\frac{1}{500}''$ in diameter; the silk threads of the worm $\frac{1}{5000}''$, while the hair lines in optical instruments are of platinum wire as fine as $\frac{1}{7000}''$. In fact, that metal has been drawn to $\frac{1}{25000}''$. These figures are interesting and instructive, but the mills which we will consider are for the production of rods intended for the cruder forms of wire.

In the early days of iron wire, the metal used was made from the ore by direct processes, and with the aid of charcoal as fuel. As only the richer, and as it happened, purer ores, were utilized, the resulting wrought-iron was of superior quality, possessing extreme softness. While the art of wire making was advancing, many other changes occurred in iron metallurgy, particularly as related to the extraction of the metal from the ore. These, as well as those changes in the subsequent working of the iron, did not all tend toward maintaining so high a class of material. As has always been the case, cheaper production was demanded in both the crude iron and finished product. To meet this condition by successfully handling the cheaper but poorer iron, more complete, and in every way mechanically better, rod mills were required. For the higher grades of iron wire, pure metal has always been, and is still, a necessity. The iron made in the direct charcoal bloomery was hammered into cylindrical masses called "blooms." These were heated in furnaces, and in the earlier days were further hammered to smaller sections called "billets," which were again heated and hammered into rods. Later, the blooms were reduced to billets and these to rods, between the grooved iron cylinders, or rolls, of rolling mills. I believe the Germans were the first to roll wire rods, and in their earliest mills the rolls were without grooves, being perfectly plain cylinders, between two of which the billet was drawn by compression. and, by their motion, forced through perforated plates placed in front of them. Evidently this idea was taken from the wire drawing plates. This could not have worked very satisfactorily, and it was not long before the grooved rolls were invented.

After the invention of the blast furnace came puddling by which the pig or cast-iron was converted into wrought-iron; but the resulting bars were too unsound and of too low ductility to

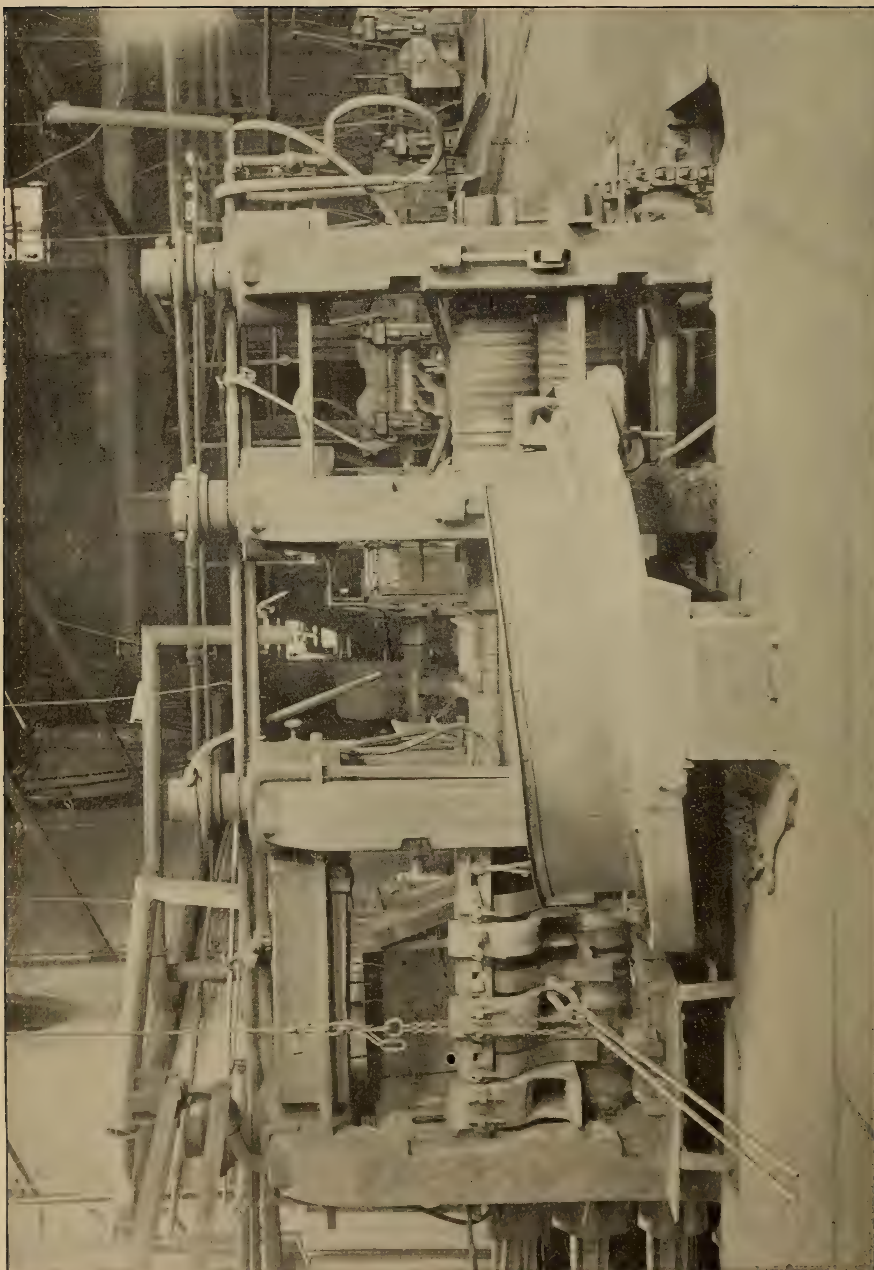


PLAN OF A BELGIAN ROD MILL.

permit their being rolled into wire rods; hence they were cut into pieces which were piled one on the other, some four to six high, heated in a reverberatory furnace and rolled into billets. These billets were again heated and rolled into rods. Such reworking of wrought-iron increases its ductility and also its tensility. As the business progressed, many improvements were made, and in no direction more than in the rod mills. The use of cheaper materials, larger productions, with less labor, were the great aims. Advancement was accomplished, but so long as iron was the metal to be treated, the highest possibilities of development could not be reached. It was not until the introduction of soft steel that these were made attainable.

The Belgian engineers made a great advance by the invention and adoption of a mill arrangement which has ever since been known as the Belgian mill. In this the rod mill is divided into two sections, the one standing behind the other and about thirty feet away. The first section has one set of rolls, which are usually of 12″ pitch line and are known as the roughing rolls. These are driven direct from the engine shaft. The other section is composed of several sets which are called the finishing rolls and are of 9″ pitch. These are driven by a belt from the engine shaft at several times the speed of the first section. On the original Belgian mills, all the manipulation was performed by hand. Later, various mechanical appliances were successfully introduced which reduced the number of men required to operate the train. A billet of 2″ to 2½″ square and from four to six feet long was about the preferred size. Owing to the comparatively slow speed of the roughing rolls, the skilled trainmen had no difficulty in catching the billet with their tongs and passing this from one groove to another. By a few passes between the rolls it was much reduced in section and greatly elongated, so that when it came from the last pass it reached to the finishing section of the train. Here another workman seized it with tongs and entered it in one of the grooves of the faster running rolls, and as it issued from the rolls on either side of the train, workmen caught it with tongs, turned it half over so that the other faces of the piece should be brought against the upper and lower rolls, and then entered it in another groove of smaller size, and so on through grooves of decreasing size and varying sections until the rod was finished, when a tube or trough led it off to a reeling machine, on which it was formed into a bundle or coil.

Previous to 1869 all wire rods were rolled in the United States upon ordinary guide mills, the manipulation of the material being entirely by hand. By "ordinary guide mills" I mean trains of rolls of about 9″ pitch, and having the several stands of rolls in the same line. On these, billets of about 1⅛″ square and 18 pounds in weight were used, and six tons of No. 4 gauge rods were regarded as a good day's or turn's work. Early in 1869 the Washburn & Moen Manufacturing Company, of Worcester, Mass., put up a continuous wire rod mill after the designs and patents of George Bedson, of Manchester, England. His first English patents were obtained in 1862. Mr. Bedson may be said to have been born in the wire business and devoted his life to it. He was connected with many of the leading wire manufacturing companies of England for many years; in fact, until his death. He was the originator of many improvements in both rolling wire rods and manufacturing wire. The Bedson type of continuous rod mills has a pair of rolls for each groove, and the many pairs necessary to complete the reduction of the billets to rods are arranged in a straight line, one immediately in front of the other. But to avoid the necessity of turning the rod during the rolling process, each alternate pair of rolls is placed with their axes in a vertical plane. Thus the first set will press upon the top and bottom of the bar, while the next set will bear against its sides, and so on. Of course, as the bar is reduced in size it elongates, and, accordingly, each succeeding pair of rolls is geared to run enough faster than the preceding pair



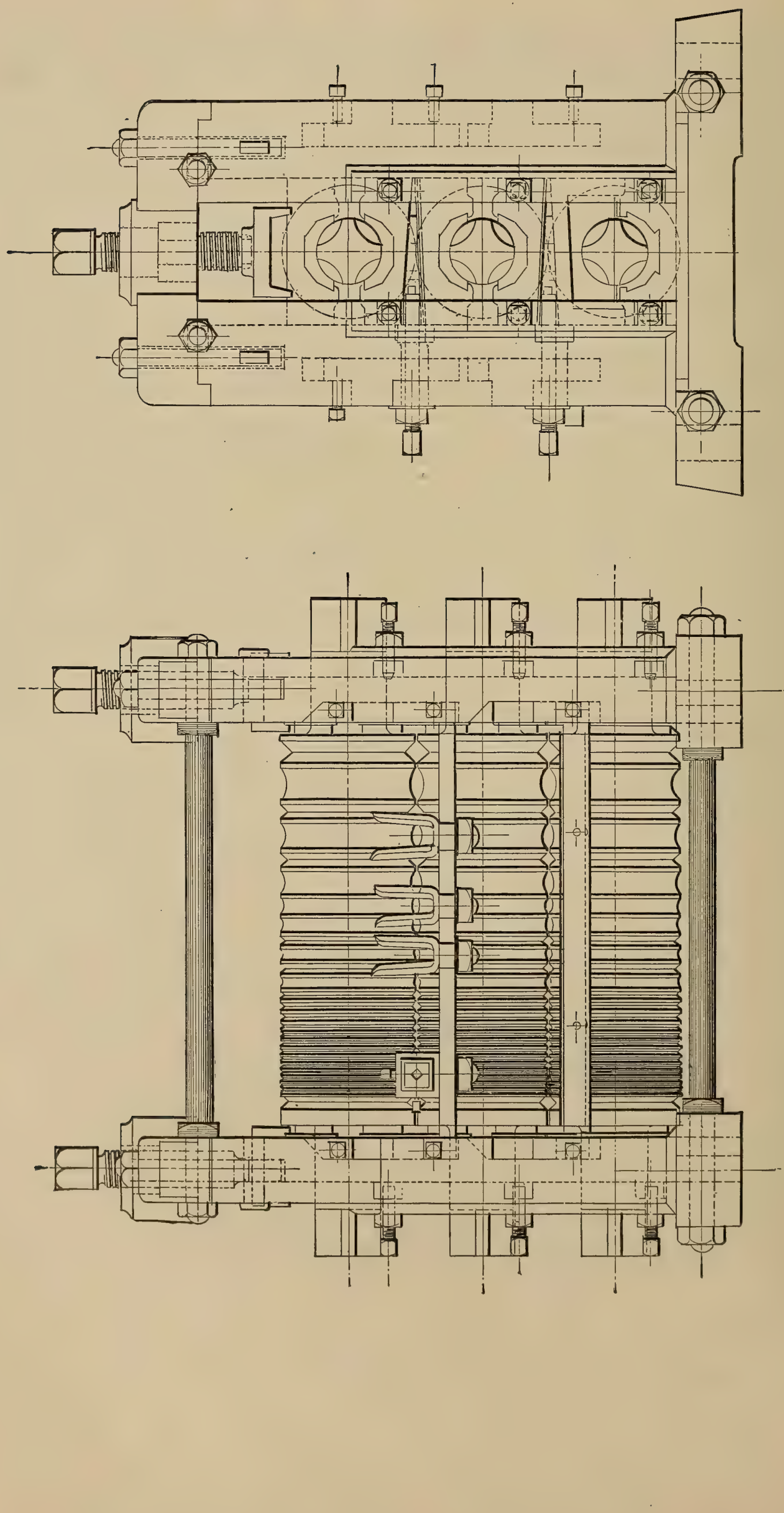
ANOTHER VIEW OF THE GARRETT ROD MILL OF THE ILLINOIS STEEL COMPANY, JOLIET, ILL.

to take up the "slack" caused by the elongation. One can appreciate the fact that nice adjustment of speed is essential to the successful running of such a mill. Billets, 1⅛" square, are used on such continuous mills, and in the early days referred to, they weighed about 80 pounds. Washburn & Moen expected to roll iron rods on their Bedson mill, but encountered so many difficulties that they were almost ready to give it up as a failure. At that time the production of soft steel had not made much progress, and iron would not stand the strains put upon it while being rolled in the Bedson mills. Snarls, messes, and break-downs were constant. These troubles were so great and their immense business so pressing that they built a mill of the Belgian type.

Fortunately it was not long before the developments of the Bessemer process gave soft steel to the trade. The use of this tough metal was the salvation of the continuous rod mill. During the struggle for existence of the Worcester mill, many changes and improvements were made in it. The well-known American mechanical engineer, Mr. C. H. Morgan, was the general superintendent of the works, and he had for assistant in this mill a bright young engineer who has since made a name for himself and is now the general superintendent and chief engineer of the Washburn & Moen Co.,—Mr. F. H. Daniels. Up to this time the reeling machines upon which the rods were coiled after being finished, had always, in all mills, been turned by hand. After the rolling of the steel billets became a success, it was soon apparent that the necessarily slow movements of the reel would keep down the output of the rolls; hence, a power reel was designed and put in by the Worcester management. Seven tons of No. 6 rods had been considered a fair turn's work. After the power reel went in, the product was soon increased to over twenty tons per turn. The length of bed of the heating furnace was increased, so that longer billets could be used, the length of which was finally brought up to 21 feet. The results were so satisfactory that the company put in another continuous mill which was designed by Messrs. Morgan and Daniels. Naturally they made many improvements over the first mill. Rods are now finished on it at a speed of 50 feet per second, and reeled with ease and certainty. Several of the improvements were patented by Messrs. Morgan and Daniels; I believe some jointly and others individually.

Since Mr. Morgan severed his connection with Washburn & Moen, he has designed and built a rod mill for the American Wire Company, of Cleveland, Ohio. This is also a continuous mill, and was started in 1888. Some very good work has been done with it. In one week the mill produced 657 gross tons of No. 6 rods. I believe the best record of weekly product has been 500 tons of No. 8 rods for three consecutive weeks. On the same mill a production of 35 tons per turn for two weeks, of No. 9 rods, 0.148" diameter, rolled from billets weighing 210 pounds, has been reached. This was a reduction of area of 99.89 per cent. The finished rods were 3620 feet long. Previous to the building of this mill, a great innovation in rod rolling had been made by William Garrett. An important and radical feature of his system is the use of a billet, 4" square. This is of so great value that all of the later mills have endeavored to use that sized billet. In the Cleveland mill Mr. Morgan departed from the original form of Bedson mill by placing the axes of all the rolls in a horizontal plane, and turning the piece being rolled, as it passes from one set of rolls to the next, by means of properly formed boxes or guides. This enabled him to have a much stronger and less complicated mill.

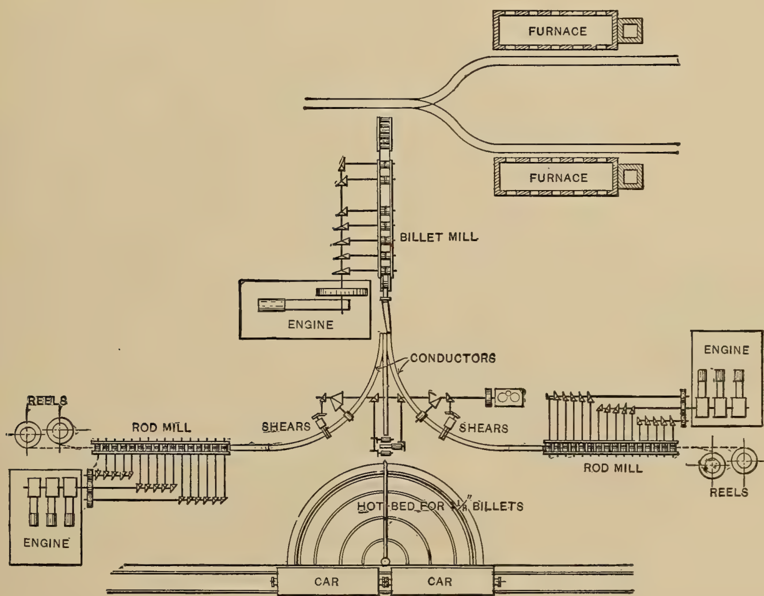
Washburn & Moen have established a Western branch of their immense establishment at Waukegan, Wis. They have there put in a rod train from Mr. Daniel's plans, which is different from its predecessors. In it one set of roughing or billet rolls feeds two finishing or rod mills. Thus, different sized



A ROUGHING ROLL STAND.

rods can be made at the same time, and a high product obtained. A few years after starting the first continuous mill at Worcester, the Roeblings, of Trenton, N. J., put down a mill on the Belgian principle. This has since been much improved and is now one of the best American mills, although I believe the output has never been brought as high as that of several of the others. The Trenton Iron Company, of the same city, have a Belgian mill. In 1876 the Cambria Iron Company, of Johnstown, Pa., built a rod mill after the designs, and covered by the patents, of Henry B. Connor. While all the rolls of the train were in a continuous line, at right angles to the mill engine, they were divided into groups, each succeeding one of which was driven at an increased speed by a line of shafting placed directly under the train. This mill was not as successful as expected, and after much experimenting it was altered and improved.

Mr. William Garrett was the superintendent of the rod mill department of the Cleveland Rolling Mill Company, Cleveland, Ohio, in 1882. In that year he built a rod mill for his company which was destined to mark an era in the American wire rod industry. Up to this time, as already stated, the continuous mills were using 1⅛″ billets, the Belgian mills, 2″ or 2½″ ones. To produce billets of these sizes upon any of the then existing billet mills, and under the prevailing practice, it was necessary to roll the steel ingot into blooms, re-heat the blooms, and roll to billets. Mr. Garrett desired to save the expense of the intermediate heating and rolling between the blooms and billets; hence, he sought to invent a mill which would take a billet large enough to permit its being rolled direct from the ingot without any re-heating. He settled upon 4″ square as being that size. Of course such a saving in heating and rolling was of great importance. To accomplish this, he went beyond the Belgian mill plan by putting in three separate trains of rolls, placed in echelon and driven at progressively increasing speeds. The first train ran at a slow enough speed to allow the workmen to handle the large and heavy billet, the second train much faster, and



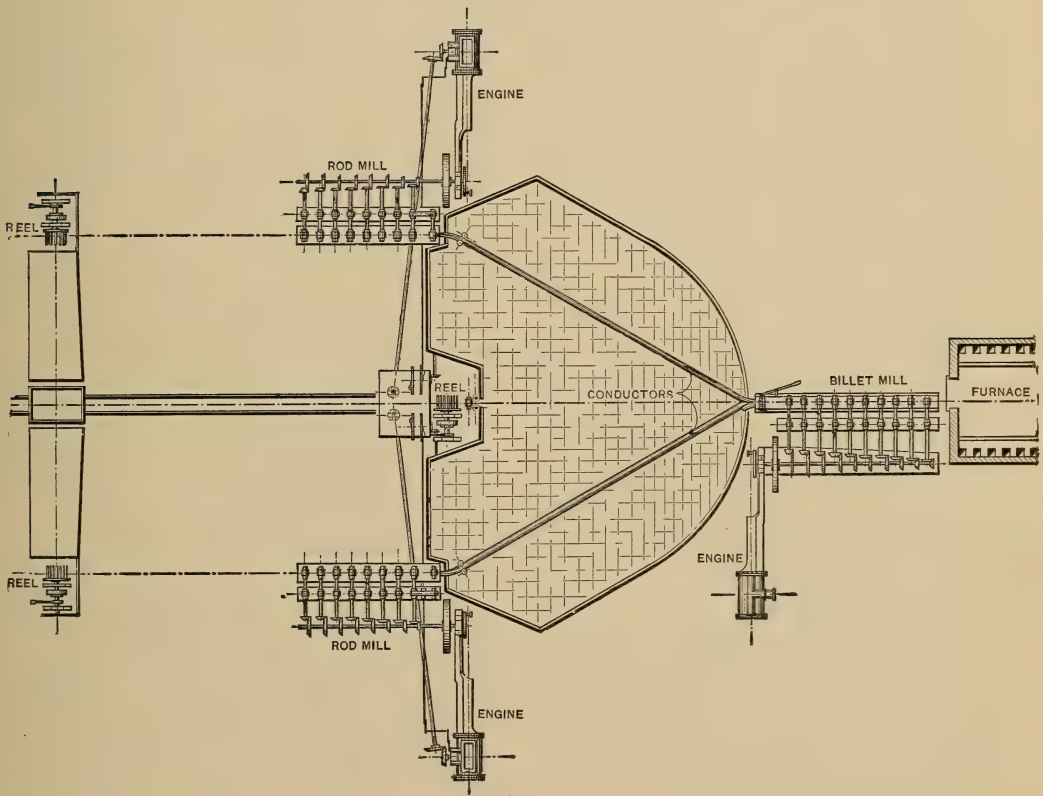
THE DANIELS WIRE ROD MILL.

as the piece had, by the time it reached these rolls, become much reduced in section and elongated, the workmen could successfully contend with a higher speed, and by the time the piece had reached the last train, which was running very fast, it was so pliable that the men could catch it with their tongs and enter it in the proper grooves. By this arrangement not only the use of larger billets was permitted, but it was made possible to have more than one piece in the rolls at the same time. This practice has grown until four pieces are now constantly, and frequently five, rolled at the same time. The success of this Cleveland mill was so great that since then Garrett mills have been put in at Beaver Falls, Pa. ; by Oliver & Roberts, Pittsburgh, Pa. ; the Braddock Wire Company, Braddock, Pa. ; the Joliet Works of the Illinois Steel Company ; the American Wire Nail Company ; the American Wire Company, Cleveland, O. ; the H. P. Nail Company, and the Newcastle Wire Company, Newcastle, Pa.

In all the later forms of mill, excepting the continuous, use has been made of what is technically called the "repeater." I presume the first applied idea of this device was made by J. Bleckly, of England, in 1872 ; at least it is so claimed. He applied this device to a train of rolls which were four high. That is, there were two sets of two rolls each, placed one above the other in the same frames or housings. The sets were driven in opposite directions. By means of a bent pipe placed with its orifices opposite grooves in both the upper and lower sets, he sought to catch the piece in the pipe as it came from the upper rolls, and carry it down to and enter it in the grooves of the lower set. In the later American mills, other than the continuous, the rolls, other than the first and larger sets, are but two-high and those of each section stand in line, each set having but one pass ; hence the American "repeater" guides the piece sideways from one set to the next, and thus from one pass to another. There is quite a controversy as to who deserves the credit for the invention of the first practical repeater. I have reason to think that John Davis, of Cleveland, has a right to the honor. A later and better one was invented by Mr. McCallip, of Columbus, Ohio. But there are several others for which their friends claim superiority. By turning and carrying the piece from one pass to another, these devices save a large amount of labor. While the advocates of the continuous system admit that larger product can be obtained on a Garrett mill, they claim a saving in labor and loss by oxidation. When wear and tear are considered, which items embrace the labor and cost of repairs, I am inclined to doubt the justice of the claim. The accurate data of each item at the various mills is very difficult to obtain. For some time the Joliet Garrett rod mill held the best record of production. Then came the Beaver Falls mill ; then the American Wire Company's Garrett mill, with a week's product of 1524 gross tons of No. 5 rods. The Garrett rod train in the Illinois Steel Company's Joliet Works made, on the "day turn" of May 28, 1894, 253,640 lbs ; and on the "night turn," 390,600 lbs., making a total of 331 gross tons of No. 4 rods for the double turn, and during this big run they obtained 94 per cent. of good rods from the total amount charged, the loss in scrap and heating being but 6 per cent. Champion honors now rest with the Oliver & Roberts mill, also built by Mr. Garrett. Of No. 5 rods they rolled in March, 1894, 6300 gross tons. How long they will be permitted to enjoy their honors it is difficult to foretell.

The Garrett train at the Joliet Works of the Illinois Steel Company, which is one of the best, is divided into four sections. The first, or roughing train, is of 16″ pitch, and the intermediate train 12″, leading or first finishing 10″, and the finishing rolls 9″ diameter. The 16″, 12″ and 10″ trains are driven by one engine, built by the Allis Works of Milwaukee, and is of the Reynolds–Corliss type. It is compounded with 32″ × 60″ high-pressure, and 64″ × 60″ low-pressure cylinders. It runs at

84 revolutions per minute. The 9″ finishing rolls are driven by a 32″ × 48″ Porter–Allen engine, making 115 revolutions. The 16″ train runs at 84 revolutions per minute; the 12″ train at 140 revolutions; the 10″ train at 310 revolutions; and the 9″ train at 500 revolutions. The finished rods are coiled on 5 power reels of the Garrett patent, which are operated by two men. Other than these reel men, there are eight men and four boys required to operate the train, in addition to the chief roller, who has charge of the entire train. The labor of these is divided as follows: 3 men on the 16″; 1 man on the 12″; 2 men and 2 boys on the 10″, and 2 men and 2 boys on the 9″ train. Of course, there is other labor to "take off" and carry away the coiled wire rods. These coils weigh from 130 to 150 pounds, with length of rods from 1000 to 1300 feet, depending upon the gauge of rod and other details of the various orders. As already stated, these are rolled from 4″ square billets, which are generally 3 feet long.



THE DANIELS WIRE ROD MILL.

The American Wire Company has one Morgan and one Garrett mill. The general arrangement of this Garrett mill is like that at Joliet, but there are several important variations. The trains are of 16″, 12″, 9″ and 9″ pitch. The first is driven by a 24″ x 42″ engine. The 12″ and 9″ leading trains are driven by a 26″ x 42″ engine, and the 9″ finishing train by a 24″ x 42″ engine. All are of the Porter–Allen type. The billets are carried from the furnaces to the 16″ rolls, in the first set of which six passes are made. One pass is then given in the next pair of rolls, and the

piece is carried by a trough or pipe to the intermediate 12″ train. In this, three passes are made between as many pairs of rolls. The piece is carried from the first to the second rolls by a repeater and trough. A pipe conducts the piece to the 9″ leading train. This and the finishing train are in line, and eight passes are made in them, the piece being "repeated" from one set of rolls to another on the front side of the trains. It is reduced from 4″ billet to rod in 18 passes.

All the later Garrett mills have sloping floors leading into pits in front of the rolls, thus helping to keep the elongating, quivering and rapidly running-out hot metal away from the rolls. Several other ingenious devices are used for the same purposes. In the old mill this work was all done by boys with hooks. The present mode not only saves labor, but is safe and allows increased product.

Less than twenty years ago, the production of steel rods in all countries was limited to the higher grades, and amounted to comparatively a small percentage of the total output. The growth of the industry in this country is shown by the facts that in 1888 the production of rods from both iron and steel was 313,341 net tons; in 1889, 407,513 net tons, while in 1892 it was 703,168 net tons. I cannot give the figures for the years anterior to 1888, as previous to that year they were not definitely ascertained. But as demonstrating how, as our own manufacture has advanced, we have gradually become independent of foreign supplies, we find that in 1886 our importation of iron and steel wire rods amounted to 153,401 net tons, in 1887 to 167,292 tons, in 1888 to 114,030 tons, in 1889 to 73,758 tons, in 1890 to 55,427 tons, and in 1892 to but 47,740 net tons. While all may not agree as to the causes and the wisdom of some acts which have brought about this change, I must be permitted to say that for one I am satisfied with it, and more than that, as an American, proud of it.

A very remarkable development in the use of wire has been in the increased production of wire nails in this country. The first American wire nails were made by William Hassall in 1851 or 1852, and the American Wire Company, of Covington, Ky., were the pioneers in the industry; and as with us all such nails are now made of steel wire, the statistics give another evidence of the substitution of soft steel for wrought-iron. While the large consumption of wire nails is a new thing in America, such does not apply to Europe; but it is also true that there, iron wire was until recently the material used in making such nails. Of course it is well known that the use of cut nails of wrought-iron was the former custom with us. About 1883, nails cut from soft steel came into prominence. James M. Swank, in his annual report for 1890 to the American Iron & Steel Association says: "In 1884 the production of steel cut nails in the United States was only 393,482 kegs, or 5 per cent. of the total cut nail production. Steel was afterward rapidly substituted for iron, until in 1889 steel cut nails represented 69 per cent. of the total cut nail production of the country." He also says:—"The maximum total production of cut nails was reached in 1886, with 8,160,973 kegs, and the maximum production of steel cut nails alone was reached in 1888 with 4,323,484 kegs." Now in 1886 the total production of wire nails was estimated to have been only 600,000 kegs. To clearly show the growth of the industry and the constantly increased substitution of wire for all kinds of cut nails, I have tabulated the figures on the next page. Another tremendous item of American wire production is barb fencing.

Without enthusiasm in our chosen calling there is not much hope for complete success. My friend Mr. William Garrett has achieved brilliant success, and those who know him fully appreciate that he is the very embodiment of energy and enthusiasm. From him I have the following figures: "I have been figuring up somewhat on the extent of the barb fence industry of this country. In 1891 there were used over 180,000 tons. One rod of the Glidden

barb fence weighs one pound. There are 320 rods in a mile. As the earth is 24,884 miles in circumference at the equator and we have 1,122,222 miles of Glidden barb in 180,000 tons, there would be enough barb wire to lap around the world at that point forty-five times. The distance from the earth to the moon is 273,000 miles. We could, from the barb wire made in this country that year, have four strands reaching from the earth to the moon, and have enough left over to go between the strands and make a "Jacob's Ladder," the only drawback being that on account of the barbs, the angels would have to be careful of their wings." All of the men who have brought the wire industry to its present status have the right to feel proud of their achievements, and our country is proud of the men.

Production of Nails in the United States.

Kegs of	1886.	1888.	1889.	1890.	1891.	1892.
Cut nails of all kinds	8,160,973	6,493,591	5,810,758	5,640,946	5,002,176	4,507,819
Wire nails	600,000	1,500,000	2,435,000	3,135,911	4,114,385	4,719,524
Total	8,760,973	7,993,591	8,245,758	8,776,857	9,116,561	9,227,343

Letters to the Editor.

DESTRUCTION OF UNDERGROUND PIPES BY ELECTROLYSIS.

There is a pleasing reference in the June number of Cassier's Magazine to my recent paper presented to the American Institute of Electrical Engineers.

It contains also an article from Mr. J. H. Vail, in which a portion of my paper, with some of the illustrations, is copied. Mr. Vail introduces the extract by saying—"Of the collection of illustrations accompanying the paper, several are reproduced together with what the author says." The inference may readily be drawn, that all that the author said is given, and inasmuch as some very important facts and considerations are omitted, I am going to ask of you the courtesy,—not to reprint my paper in full—but simply to give my conclusions summed up in eleven brief paragraphs. Your readers will then see exactly the results reached in the paper, and concurred in by the lengthy discussion at New York and Chicago. If, on reading the conclusions, they wish to study the paper as a whole, they will be able to find copies of it.

Hoping that out of fairness to all, and with a wish to serve your patrons to the fullest extent, you will accede to my request, I am, yours very truly,

I. H. Farnham,
Electrical Engineer.

[We cheerfully give space to Mr. Farnham's conclusions, which read :—

1st. All single trolley railways employing the rails as a portion of the circuit, cause electrolytic action and consequent corrosion of pipes in their immediate vicinity, unless special provision is made to prevent it.

2d. A fraction of a volt difference of potential between pipes and the damp earth surrounding them, is sufficient to induce the action.

3d. Bonding of rails, or providing a metallic return conductor equal in sectional area and conductivity to the outgoing wires, is insufficient to wholly prevent damage to pipes.

4th. Insulating pipes sufficiently to prevent the trouble is impracticable.

5th. Breaking the metallic continuity

of pipes at sufficiently frequent intervals, is impracticable.

6th. It is advisable to connect the positive pole of the dynamo to the trolley lines.

7th. A large conductor extending from the grounded side of the dynamo, entirely through the danger territory and connected at every few hundred feet to such pipes as are in danger, will usually ensure their protection.

8th. It is better to use a separate conductor for each set of pipes to be protected.

9th. Connection only at the power station, to water or gas pipes, will not ensure their safety.

10th. Connection between the pipes and rail, or rail return wires, outside of the danger district, should be carefully avoided.

11th. Frequent voltage measurements between pipes and earth should be obtained, and such changes in return conductors made, as the measurements indicate.—THE EDITOR.]

THE STATUS OF THE ENGINEER.

During the fall of 1890 there appeared in the columns of the Engineering and Mining Journal, two articles from the pen of Mr. Wm. Kent, member of the American Society of Mechanical Engineers, entitled "An Engineering Opportunity at the World's Fair." These articles, in brief, called the attention of the engineering profession to the possibilities which would undoubtedly be afforded to its members, at the then approaching Columbian Exposition, not only to show to the world what they could accomplish, but also to bring together, for comparison and study, all the different mechanisms, appliances and processes designed for mutual benefit and advancement. These articles were as able as they were timely, and at once struck a responsive chord, not only where they were casually read but also where the power laid to act upon the suggestions embodied in them.

The chief engineer of the Exposition, Mr. A. Gottlieb, a man of broad intelligence and high standing in the profession, at once showed his appreciation of the ideas advanced and expressed his active sympathy in encouraging a movement toward carrying them out. He wrote to the President of the American Society of Mechanical Engineers, asking for the co-operation of its members, and in reply he received a cordial offer of their support. The Society did not stop there. It appointed a committee, composed of some of its most prominent members, including most properly Mr. Kent, the author of the movement. This committee went actively to work and formulated plans and suggestions to be submitted to Mr. Gottlieb. The latter, however, suddenly resigned his position, and from that time on the engineering profession was never in evidence before the Board of Control of the Exposition.

The Society, when its committee was ready to report, was referred to the "Bureau of Awards," a creation which, from its inception, was mysterious in its nature as well as in its actions. All further attempts on the part of the Committee to obtain a hearing, although prosecuted with zeal and against rebuffs, were absolutely fruitless. Out-generaled at the outset, the engineering profession was never heard of during the Exposition. Another one, however, had in the meantime entirely occupied the field. The architectural profession, younger in its formation, but close in its corporate organization, led by one of its members, who held the confidence of the moneyed interests invested in the Exposition enterprise, pushed boldly to the front and nobly held its own, not to the absolute exclusion of the others, for it depended upon them, but to their complete subjection. Throughout the Exposition the engineer was not allowed recognition as the co-designer and co-elaborator with the architect, but was his acknowledged subservitor.

When, in return for invaluable services to the architectural profession, the architects of the country gave a dinner at New York city to the Chief of Construction, and presented him with a sil-

ver loving cup, he stated the situation in the following words :—"I feel that undue prominence has been given to the mere quickness with which the Exposition has been built. It is not to me the most admirable feature of the enterprise, for in the last decade or two one could go out in the street of a great city and collect a force of engineers and draughtsmen very much as formerly he hired mechanics. The times have multiplied the corps of trained technical men, and we can now in months do the former work of years. But that which is wonderful and which I can scarcely believe, although I have been in the midst of it, is the noble artistic result which has come from the work of a few American artists, who have had only a few months' time to prepare those very designs for the great buildings of the Exposition, which have actually been executed with little change from the sketches which were presented in February, 1891." True, but he might better have said, "executed by the engineer from the sketches presented by the artist." That was exactly the attitude of these professions at the Exposition. No competition was allowed among the architects. A corps, composed of the most competent representatives of this profession in the country, was formed and amply remunerated for its labors, but whenever an able engineer was called, the actual value of his time in the market, which would have to be met to obtain his services, weighed against him, and he was not accepted.

It was with the feeling that had the engineering profession been organized, so as to have possessed the prestige of a great national body, it would have compelled recognition at the hands of the authorities of the Exposition, that I presented, at the annual meeting of the American Society of Mechanical Engineers in 1892, the situation as I understood it, and suggested that its consideration be taken up by the General Committee of Engineering Societies having charge of the Engineering Congress, with the idea of bringing the subject before that body for a general discussion. I had hoped by such a method of procedure to have obtained a very general consensus of opinion as to the best means of raising the status of the profession. My desire was to seize the first opportunity which would approach to organize the profession so as not again to allow such opportunities to slip from us as the one which Mr. Kent's pen had so graphically pictured two years before.

The Society listened attentively to my paper, and many of its members entered into its discussion. They disagreed with some of the details of my suggestions ; they agreed, however, with its main features, but no action was taken. The Engineering Congress went by, and although every section touched upon the subject as one which needed serious consideration, no attempt was made to obtain a general discussion as to the best method of reaching the desired end. The Society visited the Exposition in a body. Did they hear the profession of engineering extolled for its labors? They judged the merits of the engineering exhibits there. Did they gather much information from the manner in which engineering appliances were shown to them? Did they not rather revel in unfeigned wonder and admiration at the beautiful picture which the architects had placed before them, and bow their head in overwhelmed gratitude that they had lived to see such sights on this side of paradise, and go home satisfied that some one other than themselves had seized "an opportunity?" Engineering there was and plenty of it, some good, some bad. Every building was a monument to engineering, from its pile foundation to its enormous trussed roof, but it was covered with decorated staff, and artist and sculptor had added embellishments until it was converted into a "triumph of architecture." Even the firm, which at the beginning of the work bore the title of "landscape engineers," were, at its close, converted into "landscape architects." The only feature allowed to the engineer was the great Ferris wheel, and if staff could have been put on that and it could have been embellished into Spanish renais-

sance, it also would have been claimed with the others. Hard work, indeed, did the company, who exploited this feat of engineering, experience, to get it accepted and located within the grounds ; and yet, it paid better than all the other concessions put together.

Is our profession to remain supine under the subserviency to which it will continue to be subjected unless an effort is made to release itself? There is no use to deny the fact that an engineer, in the office of a man possessing some skill in design and fair business intelligence, becomes a draughtsman and makes his employer an architect. The former gets his days' wages, while the latter receives the credit and emolument under established fees. Organization, with a high standard and the maintenance of what is right and due to its members, is the duty of the engineering profession to-day. Adherence to these principles is what has placed the American Institute of Architects on the vantage ground which it now occupies. Nor is it at a standstill. Even now it is knocking at the door of the Treasury Department of the Government to demand that the design of public buildings be made competitive to its members. Aggressiveness and push are characterizing its methods.

The Canadian Society of Civil Engineers has this subject under careful consideration now. Are its sister societies in the United States to be behind in the race? Let there be formed a National Institute of Engineers. Let this body go before the government and demand the sole authority to confer the title "Engineer." Let this body co-operate with technical schools through the Society for the Promotion of the Engineer's Education, to the end that their courses shall be homogeneous. Let only those men practice who have received the title, or practically a license, from this Institute, and let this title be given to the applicant on passing an examination, be he college bred or from the field. Then let a minimum fee for services rendered be established. Our standard will soon be borne to the front under such a change of policy.

I am informed that one of our local societies, centrally situated in the United States, contemplates reorganization on a broader and higher plan. When this comes about, let the engineers of the country rally to it and make it *de facto* a National Institute of Engineers, on the lines which I have mentioned. Let us assume the aggressive and prepare ourselves to properly meet the next opportunity which opens to us. Thus will an opportunity lost bring about quickly, results which otherwise would have required years to mature. So severe a lesson read to us at such a time should effect a most salutary end.

H. F. J. PORTER.

A NEW MINE PUMP.

By Richard Thomson.

THE mechanism of this pump, recently described before the Mining Institute of Scotland, is simple and easily got at for repairs. Its working parts are much lighter than those of other pumps. As a consequence better results are obtained from the engine. It is a great convenience also that the pump takes up very little space in the shaft.

As in ordinary force pumps, there is a suction-pipe, clack-piece, and ram-casing, with stuffing-box. The ram is made hollow inside, and is turned on the outside. Immediately on the top of the ram is the clack-piece, which moves

upward and downward with the ram. On the top of the ram clack-piece, steel-tubes are built up to the pit-mouth. The hollow ram and tube serve the double purpose of pipe and pump-rods. At the pit-mouth a short steel casting, the inside diameter of which is the same as that of the tubes, is put on, with a stuffing-box on each side, their united areas being equal to the area of the tubes. Into these two short knee-pipes are inserted, one end plain and turned to fit the stuffing-boxes, the other flanged to fit a Y-pipe. The united lengths of the knee-pipe and Y-pipe are equal to the bell-crank arm. The single end of the Y-pipe rests on a roller under the main centre of the bell-crank. The connection at the top of the steel casting is a strong, malleable iron blind flange, with short clivis rod and brasses to fit the bell-crank, and secured through the flange with a screw nut and cotter. This Y-pipe discharges the water always at the same level.

The tubes are stiffened in the shaft by means of cast-iron rollers, the grooves of which fit the diameter of the tubes. They are put on in pairs at intervals of 32 feet, beginning at the first tube above the ram. Spindle-valves are used, formed of a conical-edged steel plate let down to the flush of the shell, resting on the edge, feathers and centre, and covered with an india-rubber web, ⅞ inch thick, which covers the plate and part of the shell. Such is the description of the pump, which may be said to combine the old bucket-lifting pump and force pump in one.

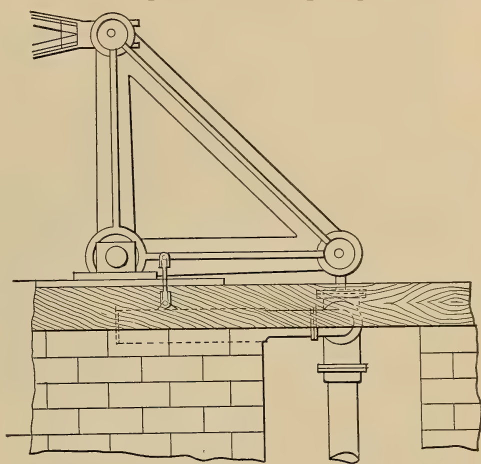


FIG. 1.

All that can be said in favor of the bucket-lift in sinking may be said of this pump, and it has other advantages in addition. The chief points in a sinking pump are not only that it be sufficient for the work, but also that it be easily kept in furnishings, easily put in working order, and that it gives little trouble to those in charge. This pump fulfills

FIG. 2.

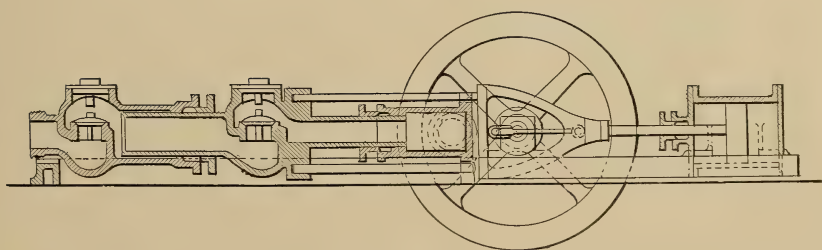


FIG. 3.

these conditions. Everything about it is light and easily handled, and it takes up little space in the shaft. In fitting it up for pit-sinking it is necessary to get the ram and ram-casing four feet longer than is required for the length of stroke of the engine, and the suction-pipe extra heavy and conically pointed, so that, however rough or uneven the bottom may be, the line of thrust downward will be through the centre of the ram-casing, clack-piece, and suction-pipe, and any tendency to knee prevented.

Let us suppose a shaft to be sunk as far as to admit of the above-mentioned pieces being put in place, with two lengths of tubes above the ram-casing, and having the short steel casting with Y-pipe permanently in place, and blind-flange and clivis rod attached to the bell-crank; also a set of rollers on the first tube above the ram, and a set of easy-fitting collaring on the ram-casing about five feet below the stuffing-box. In order to lower the pump as sinking proceeds, it is only necessary to rest the ram at the bottom stroke, cut the joint immediately above the ram clack-piece, signal the engine to the top stroke, fix a four feet tube on the top of the ram clack-piece, lower by means of the engine, and fix the other joint. At the next lengthening, the four feet length of tube will be taken out and an eight feet length put in, the process being repeated in lengths of four feet until a sixteen feet length, which is the usual length of complete tubes, can be put in. These operations may be continued to the depth of 100 fathoms if required, provided the tubes, flanges, bolts, and other fittings are made heavier in proportion to the greater depth. The pump can go partly on air and get rid of it as easily as the common bucket. It resembles the bucket-pump in this respect, that it lifts one-quarter of the weight of water in the upward movement, and it resembles the ram-pump in the downward movement by having three-quarters of the weight of water to displace. The weight of the tubes assists the engine in the downward movement, and the balance is almost equal at any depth with one bell-crank, which is a great advantage in sinking. No powerful crane is required to work about the pump, as the heaviest pieces are the ram and ram-casing, all the other pieces are light.

Fig. 3 shows a special pump of very simple construction with hollow rams. It has a sole-plate, on which are placed the two ram-casings, crank-shaft, fly-wheel and cylinder working direct on the rams. The crank revolves inside the part which connects the piston to the rams, and may be worked either by steam direct or by a clip-pulley on the crank-shaft driven by wire-rope. The two rams and discharge-clack seat are made in one casting, and carry the valve backward and forward as they move in their stuffing-boxes. The receiving end of the ram is double the area of the discharge end, and in the receiving end of the ram-casing a valve is placed, as in other pumps, to check the water that finds its way past it. The small end of the ram determines the size of the pump. The quantity of water that will be discharged in its backward and forward movements keeps up a continuous flow equal to the diameter of the small end of the ram.

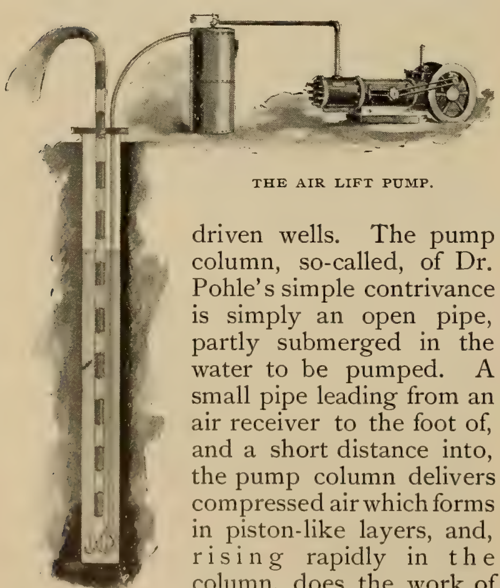
Current Topics.

ENGINEERS all over the country will be interested in learning of the recent break-down of the remarkable fast-running Corliss engine which, for years, was in operation at Trenton, N. J., driving one of the rolling mills of the Trenton Iron Company. One hundred and sixty revolutions per minute was the regular speed of the engine,—a speed which never before had been obtained with any form of drop cut-off gear, like the Corliss, and which even to this day stands unparalleled. At the time that the engine was put in service, and even before that, there were many who predicted that it would be a failure; that no Corliss engine would stand such high speeds, and that the engine would be in the scrap heap within six months after it was started. Time, however, showed that these apprehensions were unfounded. The record of the engine, in fact, was a most enviable one. There had been only a few brief stoppages in sixteen years, and in 1893 the engine ran, on an average, eighteen hours a day with a varying load ranging up as high as 700 horse-power, though 450 was considered about the maximum that it should be called upon to perform. There was nothing specially novel in the construction of the engine over those which Mr. Corliss regularly built, excepting that the steam ports were larger than usual, and the valves were made as light as possible, being cored out to reduce the weight to the minimum. The releasing mechanism was also exceedingly light.

IT was to the breakage of a piece of this modified gear that the accident was due. The break prevented the valve from cutting off on one end of the cylinder, although the governor was in working order and controlled the cut-off of the other end perfectly. As soon as the fracture occurred, the engine began to cut-off at the beginning of the stroke on one end, to carry steam full stroke on the other and to race. The attendant did all he could to stop the engine, but was obliged to give up the attempt after having closed the throttle from a full opening of four inches to one of less than half an inch. He just escaped as the fly-wheel burst, sending its fragments directly through the space which he had occupied but an instant previous. One piece went

through the roof of the mill, and another through the end of the building about 400 feet off. Mr. Samuel S. Webber, assistant manager of the Trenton Iron Company, in a recent letter tells us that the engine is now running again, having been fitted with a new shaft, new fly-wheel, new main bearings and a new pedestal. Several portions of the frame also had to be replaced, besides many small parts. The engine, therefore, would seem to be good for still another prolonged period of usefulness.

THE air lift pump, as it is now generally known, devised several years ago by Dr. J. G. Pohle, of San Francisco, though not at all a pump in the proper sense of the term, has, of late, become a much-used water-works adjunct in several municipalities and is credited with most satisfactory results in the way of raising water from



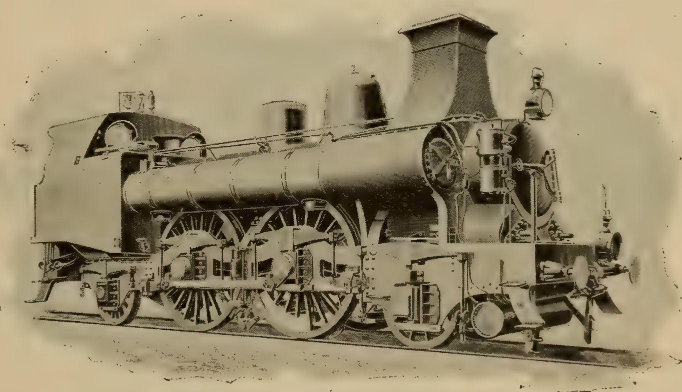
THE AIR LIFT PUMP.

driven wells. The pump column, so-called, of Dr. Pohle's simple contrivance is simply an open pipe, partly submerged in the water to be pumped. A small pipe leading from an air receiver to the foot of, and a short distance into, the pump column delivers compressed air which forms in piston-like layers, and, rising rapidly in the column, does the work of pumping, the water being discharged in alternate layers with the air. Plungers, rods, buckets, suction, foot and discharge valves there are none; in fact, there are no ordinary pump parts whatever, and mud and sand, which are usually somewhat troublesome to conventional pumping machinery, can be handled with impunity. One feature of the system deserving favorable comment where it is applied to town water supplies is that the water raised is cooled by the expansion of the air and is thoroughly aerated, acquiring a most desirable life and sparkle. But it is not the lifting of potable waters alone from wells to which the system is limited, and the draining of mines and excavations, the raising of liquids which damage the working parts of pumps ordinarily used, and the increase of lift and capacity of other pumps by the introduction of an air jet into the pump column may be cited among the numerous possible applications.

AN early application of the principle of the air lift pump was made a number of years ago in the course of the several spasmodic attempts to drive a tunnel under the Hudson river at New York. How to get rid of the soft mud excavated from the tunnel headings, in a manner at once expeditious and economical, was one of the problems under consideration. It was eventually solved by thinning the mud to a quite fluid consistency by the addition of water, and in this state it was forced by the air pressure in the headings through a pipe line leading from a receiving trough in the headings to a suitable place for deposit on the surface, some distance away from the mouth of the tunnel. Although the length of the pipe line was quite considerable, no difficulty was encountered in the working of the scheme. Its simplicity and convenience commanded attention. The pipe were simply laid down, and a slight additional tax was put on the air compressors already in use for supplying air to the headings. A somewhat similar plan of conveying semi-liquid matter is now in operation in some places in connection with the manufacture of earthenware, the clay, in a properly prepared state, being carried by it through pipes over short distances, from one building of an establishment to another.

THE subject of raising and conveying liquids recalls also an expedient adopted in connection with the sinking of the caissons for the pier foundations of the great Forth bridge in Scotland. A form of hydraulic shovel was used in the caissons in digging through a stratum of very tough boulder clay, and some means had to be provided for getting rid of the waste water from this machine. In order to avoid distressing the workmen, the air pressure in the caisson, after the latter had been made tight against the entrance of water around it by sinking the edges into the clay, had been allowed to fall to a point much below the hydrostatic pressure due to the head of water above it. It, therefore, was doubtful whether, with an atmosphere relatively so attenuated, the pumps on the surface would lift the waste water through the sixty or more feet of rise. The very simple plan was accordingly followed of setting the suction pipe of the pumps in such a manner that air was drawn in with the water. In passing into the pipe together, the air and water were churned into a sort of emulsion, of course lighter than water alone, and this mixture was easily discharged from the upper end of the delivery pipe without resorting to force pumps. This notion of taking advantage of the reduced weight of a mixture of water and air, as compared with the weight of water alone, was, however, even at that time not so very new, and had been applied in many instances in lifting water through heights ranging from about twenty-eight to thirty-six feet. The noteworthy feature in the case of the Forth bridge caissons was the comparatively great height of from sixty to seventy feet.

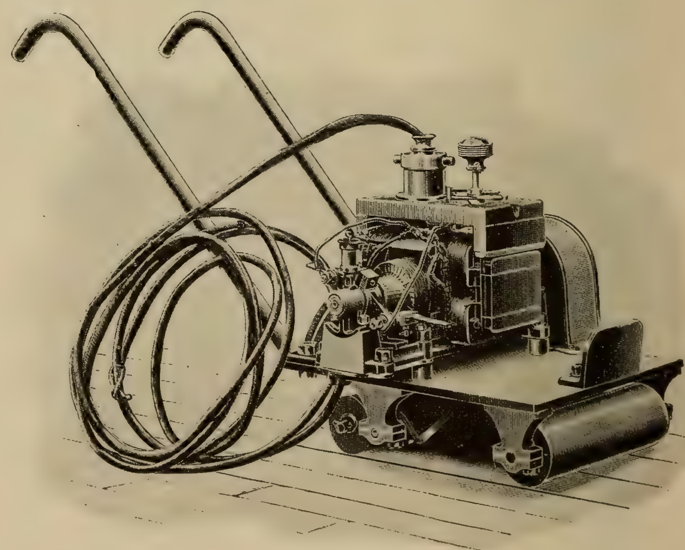
ONE of the most unconventional developments of locomotive practice since the time of Stephenson is found in a triple-boiler engine, built some time ago for the Belgian State Railway, and described in a number of foreign engineering periodicals. As implied by its name, the engine has a boiler with three barrels all having the same fire-box tube-plate, and the same extension smoke-box. The chimney is square, spreading out at its base to embrace the side divisions of the smoke-box,—an arrangement designed to improve the draught in the side flues. As regards economy, the results given by the engine are said to be excellent. Certain details of construction, on the other hand, have been criticised as capable of improvement, such as, for example, the square chimney in which, it has been held, the exhaust steam probably acts less efficiently as a draught producer than in a round one. The square design, moreover, certainly obstructs the view ahead somewhat. Then, again, there are no running boards permitting the engine to be got at when under way, and there is also, sometimes, an unequal expansion of the tube-plate, due to a better draught in the central series of tubes than in those at the sides. As a means, however, of increasing the steaming capacity of a locomotive boiler, the design is worthy of note, the more so as it does not represent simply an untried experiment, but has been in actual regular service for a reasonable period.



A TRIPLE-BOILER LOCOMOTIVE.

THE fact that iron in a very finely divided state, when exposed to the atmosphere, may oxidize so rapidly as to practically take fire, is pretty generally known. The circumstance is brought to mind by a newspaper waif reporting an incident of the Alexandria bombardment in Egypt, a dozen years ago. A shell belonging to one of the English ships had passed into a house without exploding and the residents subsequently requested the removal of the unwelcome guest. A number of men were accordingly sent ashore, and after some consideration as to the best plan to be pursued in removing the dangerous missile, a feather bed was procured and the shell firmly enveloped in it. It was then carefully rolled downstairs and was probably thrown into the sea. To show, however, that this was by no means convincing evidence that its dangerous properties were destroyed, the case was cited of an iron shell which had lain under water for about two hundred years and which, when brought to the surface, was so completely honeycombed by the sea water and presented metal in so fine a state of division that, to the horror of the surprised finder, it gradually steamed fiercely and became red hot. From this it was argued as not at all improbable that a similar occurrence might take place with the shell of the later period, and that if, in after years, it should be found and brought to the surface, its finder might be surprised in much the same way.

APPLYING the lawn-mower principle to the making of a planing tool, a Scotch engineer, Malcolm Sutherland, of Dumbarton, has designed the rather unique piece of apparatus shown in the annexed sketch, and consisting, in brief, of an electrically-driven revolving cutter, mounted in a frame on rollers which, by means of handles, can be moved about in exactly the same way and quite as easily, it is claimed, as the garden tool mentioned. The lawn-mower resemblance, in fact, is perfect. The frame, or rather base-plate, is of steel, and carries the cutter on its under side, while the motor is placed on top and drives the cutter through intervening gear wheels, giving it a speed of 3000 revolutions per minute. The hind roller of the base-plate, which follows in the cut, is fitted with eccentric journals so that, by moving a lever, they can be raised or lowered and the depth of cut nicely adjusted. The principal field of the machine,—the one, in fact, for which it was specially designed,—is the planing of ships' decks, taking off the pitch and inequalities of the seams of deck plank after being laid and calked. This work has usually to be done in circumstances of considerable inconvenience and disagreeableness, the carpenter having to go down on his knees, driving a jack plane before him, together with wood shavings and other things less clean. Ordinary floor planing,



AN ELECTRIC FLOOR PLANER.

however, can obviously be done by the machine with fully as good results, so that it is not necessarily restricted to shipyard use.

One of the things which it seems difficult for the public mind to grasp is that there is a decided difference between the knot and the mile. It is certainly about time to have it thoroughly understood that the two are not the same thing. It seems easy enough to remember that a mile is only about 87 per cent. of a knot, the latter being, approximately, 6082 feet in length, while the statute mile measures 5280 feet. Three and one-half miles are equal, within a small fraction, to three knots. The result of this difference, of course, is that the speed of a vessel in miles per hour is always considerably larger than when stated in knots, and the confusion of the terms sometimes gives rise to rather remarkable claims of speed performance. When a 20-knot ship, for example, is lightly mentioned, it should be remembered that this really means a little over 23 miles; similarly, with higher figures which are often glibly enough stated, the difference between the terms is worth bearing in mind. It will help to guard against the forming of ridiculous estimates of a vessel's capabilities.

It is a half-hourly occurrence with every electric trolley car that the trolley wheel leaves the wire, usually at a curve or a crossing, stalling the car and not infrequently causing a pretty close approach to profanity on the part of the conductor whose duty it is to bring everything back to ship shape. It is somewhat to be wondered at, therefore, that inventive progress has not yet given birth to any thoroughly satisfactory device for maintaining uninterrupted communication between a trolley wire and a car. Putting projecting prongs on each side of the trolley wheel, to catch the wire as the wheel tends to slip off, has been tried at Chicago with fairly good results; but, after all, this expedient represents only a partial solution of the problem. On one German road, built at the city of Barmen by the well known Berlin firm of Siemens & Halske, the conventional trolley wheel has been entirely abandoned, its place being taken by an oblong metal frame, the upper side of which bears against the under portion of the conducting wire. The frame is supported by something analogous to a trolley pole and the theory of action apparently is that the width of the frame will permit considerable lateral movement without breaking contact. No particulars are available to show what degree of satisfaction this contrivance has given, though it is fair to presume that Messrs. Siemens & Halske have reasonably well assured themselves of its good working before installing it. Without knowing more of its details there would seem to be a likelihood of the frames tilting and catching in the span wires supporting the main line.

A GERMAN TROLLEY WHEEL SUBSTITUTE.

One advantage which electric arc lights have, on several occasions, been pointed out to possess over all other means of illumination, is that they give off a very large proportion of chemical rays and, accordingly, closely simulate the effects of sunlight. Dark rooms,

cellars and other places into which sunlight does not come, and which are usually unhealthful, may, therefore, be expected to become quite as desirable from a purely sanitary point of view, and to be as easily protected from foulness when arc lights are used in them as rooms to which sunlight has free access. In dark stores and other establishments the introduction of arc lights ought, consequently, to have a decidedly beneficial effect upon the health of employees and should relieve them, to a considerable extent, from the attacks of diseases produced by want of sunlight. A practical demonstration of this power of the arc light can readily be obtained by remaining for a short time in close proximity to a large light when it will be found that all the effects of sunburn will be produced.

THE recent reduction in price of aluminium has called renewed attention to the possibilities of the use of aluminium-bronze castings for purposes in which the strength of forged steel without its liability to corrosion are all essential. Its price should now be not much above that of ordinary gun bronze. A 10-per cent. aluminium-bronze would figure up, say—90 cents for 9 pounds of copper, and 60 cents for 1 pound of aluminium, making a cost of 15 cents for a pound of the alloy, to which should be added something for loss, said to be very small, and the cost of labor, fuel, etc., for mixing and melting. The greatest objection to the use of the alloy at present is lack of common knowledge of how to overcome the difficulties of casting it. At the temperature of pouring, the aluminium in the alloy appears to have a tendency to rapid oxidation, producing a film which is apt to make flaws in the casting, similar to what are known as "cold shuts" in iron castings. It is also exceedingly liable to form blowholes in the interior of the casting. As a speaker at a recent meeting of engineers said, the difficulties of making steel castings are not to be compared with those of making aluminium-bronze castings. In those foundries which have made a success, more or less, of such castings, there seems to be a tendency to keep the methods secret, and to ask very high prices for their product. This is short-sighted policy. The high price limits the extent of the market, and the secrecy with which some founders surround themselves is apt to shut them out from sources of information which otherwise might be open to them, and prevent their own progress. They should take a lesson from the history of the Bessemer steel industry in the United States, the founders of which shared with each other their records of progress and had no secrets, the result being extraordinary development of the industry within a very few years, and the enrichment of nearly all connected with it.

Yours truly
Henry Morton.

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CASSIER'S MAGAZINE.

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THE FERRYBOAT OF TO-DAY.

By Col. Edwin A. Stevens, President Hoboken, N. J., Ferry Company.

A FERRY is, in law, the continuation of a highway over a stream. It partakes of the nature of a bridge and serves the same purposes. Many are the forms which the ingenuity of man has devised to accomplish this end, and all kinds and shapes of craft, propelled by every form of power known to the naval designer, have been and are used. Passing by the primitive pole and paddle as well as the more effective oar, manual power has been used for driving winding machinery; the power of the winds, of currents, of horses, and of steam have been or are used, and even electricity is now suggested. We find in almost daily use all of these sources of power, applied more or less simply and effectively. Each in its own sphere has done, and still does, its work. It is well to remember that the surrounding conditions fix, to a great extent, the solution, and that every problem does not and cannot admit of the same, or even of a similar, answer.

Perhaps the simplest form of propulsion, leaving out manual power, is the use of the energy of the current of a rapid stream. On a cable, stretched from bank to bank, runs a trolley, to which the ends of the ferryboats are fastened by ropes. Trimming these ropes so that the forward end of the boat points up stream will give a thrust on her side, a component of which thrust is in a direction across the stream and is utilized as propelling power. This action of the current is similar to that of the wind on the sails of a vessel when the wind is abeam ; the hull itself takes the place of the sails, and the connections to the cable supply the lateral resistance which, in the sailing vessel, is furnished by the hull and keel, or centreboard. Of sail ferryboats, a peculiar and ingenious type is still in use on Lake Champlain. In the rivers of continental Europe the winding of a cable on a drum on the boat itself is often met with, and the same system is successfully used at the Brooklyn Navy Yard. Besides the turning of such drums, steam is used mainly to drive either the paddle wheel or the screw-propeller, and to-day these are the most advanced means of boat propulsion.

The City of New York, with its great surrounding waterways, has been, is

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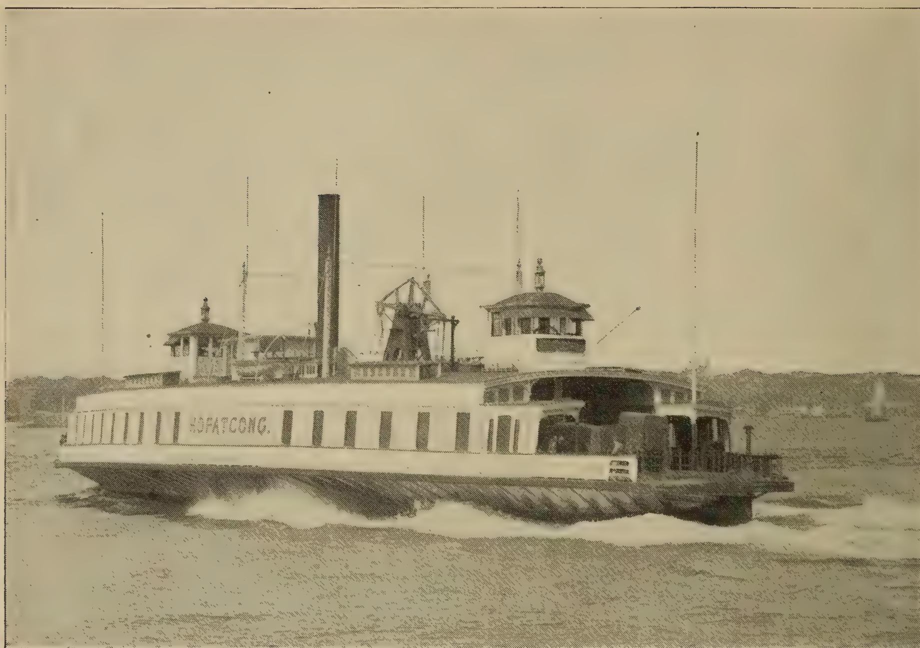
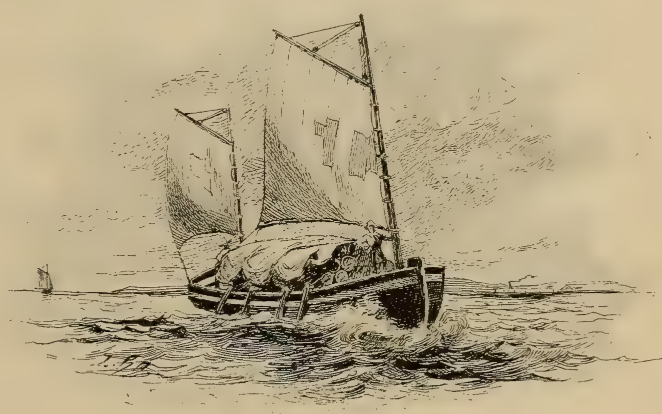


A SINGLE-DECK PADDLE WHEEL FERRYBOAT.

A DOUBLE-DECK PADDLE WHEEL BOAT.

and must be always, the home of the ferryboat. Its broad rivers and bays, its concentrated and active business, and its restless, crowded population have helped to produce a fleet of ferryboats as yet unrivaled elsewhere. From the most primitive beginnings we can trace the history of this development. In 1659 the Long Island farmer used to summon Cornelis Dircksen with a horn which that archaic ferryman had hung on a tree, so that by means of its music he might be apprised of the arrival of a customer. In those days canoes carried our easy-going ancestors leisurely and pleasantly across the East and North rivers. Then came larger row-boats and sail-boats which, in their very name, periauger (pirogue), recorded their kinship to an aboriginal predecessor. Then came a great step forward, the horse or team boat. This magnificent vessel, which came in with the early years of this century, was so commodious that it was actually possible, in the later ones, to drive on board without unhitching one's horses. A catamaran with a radial wheel between the hulls was the usual type and long held supremacy, for in 1812 we find that Col. John Stevens withdrew from the Hoboken ferry the first steam ferryboat, the little Juliana, in favor of the "more convenient" team boat.

How much Fulton's and Livingston's monopoly of New York waters for purposes of steam navigation had to do with this convenience is not recorded. But even earlier than this, in 1804 and 1805, there had been run over what is now the route of the Barclay Street ferry at New York a small twin-screw boat with a water-tube boiler. This boat's engine and a reproduction of her hull were exhibited at Chicago, and are now in the Smithsonian Institution at Washington. She was not a ferryboat; in fact, she was an experiment and, though only partially successful, she established the practicability of steam propulsion and of screw propellers. In 1810 Fulton arranged with the Jersey associates for a steam ferryboat, the Jersey, which went into service in 1812 on the Pawles Hook, now the Courtland Street ferry. She was, like the horse boats, a double-hull vessel with a central water-wheel, and measured 80 by 30 feet over all. She was followed by other similar boats, which, however, proved so unpopular in the long run that in the thirties there were threats to organize mobs to sink this type of vessel. This, however, was after the public had become used to the faster and better single-hull boats. Boats of the double-hull type were also built from Fulton's design for the East river.

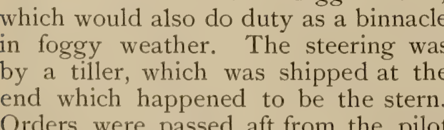


A PERIAUGER.

In 1822 and 1823 the Hoboken Ferry returned to steam in the Hoboken and Pioneer. These vessels were very fast for their day; in fact, they were probably the fastest boats then afloat, making their run of 1⅓ miles in about seven minutes. Men, to-day working on the Hoboken Ferry, remember these boats and served on them, and from their descriptions the sketch of the Fairy Queen on page 279 was made. She was built in 1828, but was smaller than either the Hoboken or Pioneer. The

THE LATEST TYPE OF HUDSON RIVER FERRYBOAT.

boats of those days had their cabins below deck. They held, at most, 100 persons and could carry eight teams. They had a drinking bar, and this was luxury not to be despised when a trip might last six hours and result in a return to the starting point for more fuel to fight the heavy ice in winter. In summer, however, the passenger had an awning spread over the deck, and, if he regarded creature comforts, might



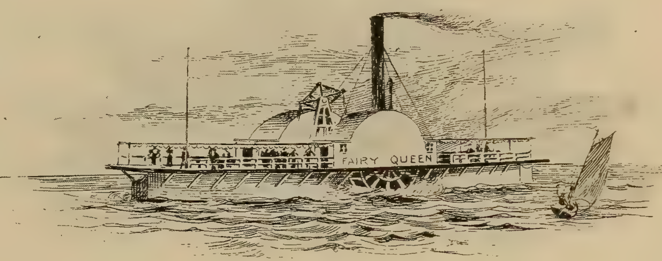
MIDSHIP SECTION OF A HUDSON RIVER FERRYBOAT.

take his ease on a three-legged stool, which would also do duty as a binnacle in foggy weather. The steering was by a tiller, which was shipped at the end which happened to be the stern. Orders were passed aft from the pilot to the helmsman. Many are the tales of the old days, of the long and fruitless fights with ice, of boats drifting aimlessly about while all hands watched a prize-fight through to its last round, of the seductive hot toddy, the great games of cards, and the wonderful yarns that were spun by "all hands, and the cook," in this case probably the bartender.

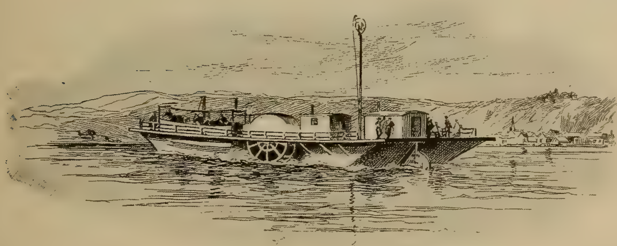
But all of this old lore is not for the readers of Cassier's Magazine. To them the fact that pine wood was the fuel and that the piston-rod was guided by a parallel motion, and not by slides, are the more important. Soon came the cabin on deck, coal fuel, cross-heads and slides, pilot houses and steering wheels, so that in the forties the type of the New York ferryboat had reached the development which all of us have known and see even to-day. Boats have grown in size, in power, in beauty of finish, and in comfort, but the engine remained long the same, and drove the boat at the same speed, but with greater regularity, over the same old waters. It would be useless to fully discuss the boats that came between these early pioneers and our present side-wheelers. Of them, suffice it to say, that they were good in their day. Their engines were simple, cheap, effective, and economical, and their descendants, even to-day, do not have to blush at the end of a year when their total expenses are compared

with those of their more modern sisters. Their hulls were, like those of all North river craft, simply and efficiently braced to enable them to carry their engines and loads, and the former had an easy way of accommodating themselves to little inequalities and deviations which would call forth many a groan and squeak from a more modern propeller engine. I will note one peculiarity of the Hoboken boats, which originated in the John Fitch and remained as long as wood was used for the hulls on that line. The frames of these boats were straight, giving the midship section the shape shown in the sketch on the opposite page. This peculiar shape had many advantages, among others cheapness and easy lines. Before passing to other matters, a word should be said of the service which ferryboats rendered in the war. They proved themselves efficient transports for inland waters, and made gun-boats whose services were not to be despised. The bones of more than one now rest in Southern waters.

The New York ferryboat engine remained practically unchanged until within the past few years. It was what is known as the American beam engine, with Stevens or Sickle valve gear, single cylinder, and jet condenser. The only auxiliaries were a fire and bilge pump and a feed pump. The wheels were radial and, until lately, mostly built of wood. The boiler pressure long stood at 30 pounds, but in the later boats rose as high as 45 and even 50 pounds. The whole arrangement was simple, easy of access, and gave good results both as regards economy and in performing the duties expected of it. Inclined engines were tried, but did not succeed in supplanting the beam engine. The first attempt, however, at improvement on the single cylinder engine was in the inclined engines of the Erastus Wiman and Robert Garrett of the Staten Island ferries. These boats have compound inclined engines and feathering wheels. While in every way fine vessels and decidedly in advance of previous practice, the step does not seem to have been in the direction best suited to the general conditions of New York waters, as no boats of their type have followed them. Of course, the inventive American mind was not content to let this state of things remain unchanged. Early in the fifties the Stevens's planned, and actually contracted with Hogg & Delamater, for a screw ferryboat, a portion of whose model is still in my possession. For some reason, now long forgotten, the boat was never built. Such men of genius as Ericsson and Erastus Wiman have suggested changes of a radical nature, and every ferry manager has probably lively recollections of many



THE FAIRY QUEEN, 1828.



THE TEAMBOAT.

and various inventors with schemes whose only merit was newness, and many of which did not have even that redeeming feature.

Ferry men, as a rule, have been unprogressive. The nature of the business renders engine economy less important than on longer routes. Good results were certain if previous practice were followed, and gains from radical changes seemed so slight and involved such risks of failure that it is not to be wondered at that for years changes were few. I can distinctly recall one incident that illustrates this conservatism. When the Orange and Montclair of the Hoboken Ferry Company were built, it was decided to adopt a square pilot house with elliptical front instead of the round one, till then in universal use. Many were the objections to this plan,—a round house was the only one from which a boat could be properly steered; accidents would be sure to happen, etc., etc. It was almost as serious a matter as launching a boat on Friday. Of course, as every pilot now knows, the square house is much the better, and no round ones have been built for a number of years.

But in spite of all this there were improvements. The Fulton and Farragut in 1871 and the Erie in 1873 were built of iron, and were the first ferryboats in New York waters with metal hulls. The stepped or half bucket and the iron wheel frame were introduced. Cabins were decorated more profusely, if not always in good taste, and in some cases hard wood took the place of the painted pine that had been universal. Compressed Pintsch gas and electric lights displaced the oil lamps that had almost driven out the city gas after the loss of the James Watt in 1870 by fire, occasioned by a gas explosion. The early boats were heated by stoves and even by open wood fires. Then came the steam radiator in various forms until the Pennsylvania Railroad Company introduced the Sturtevant system of forced circulation of heated air,

A CALIFORNIA ROPE FERRY.

A DOUBLE-SCREW BOAT OF THE PENNSYLVANIA RAILROAD COMPANY.

driven by a fan, and supplying by far the best means of securing that most desirable end,—even temperature and good ventilation. The automatic regulation of the air currents by means of rheostats, introduced on later boats, has brought this system to a point approaching as near perfection as the difficult conditions will permit. Steering by steam was also introduced on the Pennsylvania ferries several years ago.

All of these advances are well shown by the cost of the boats. The Pioneer of 1823 cost $16,874.50; a wooden boat in the fifties cost about $50,000; the Montclair, the last of the North river side-wheelers, cost $120,000, and a screw boat, like the Cincinnati or Bremen, costs $180,000. While these improvements were going on, there had been progress ashore also. Even the engineer is apt to forget the problem that here meets the ferry man. Every time a boat makes a landing a weight of from 1,300,000 to 2,000,000 pounds has to be stopped, and when the slip is full of ice this cannot be done with a side-wheeler's engine and allow the boat to reach the bridge. At even the lowest speed the energy of the moving mass is tremendous. Early in the century Col. John Stevens abandoned the old bridge which was carried on the boat and adopted a floating

A STATEN ISLAND, N. Y., FERRYBOAT.

THE FOUR-SCREW FERRYBOAT OXTON.

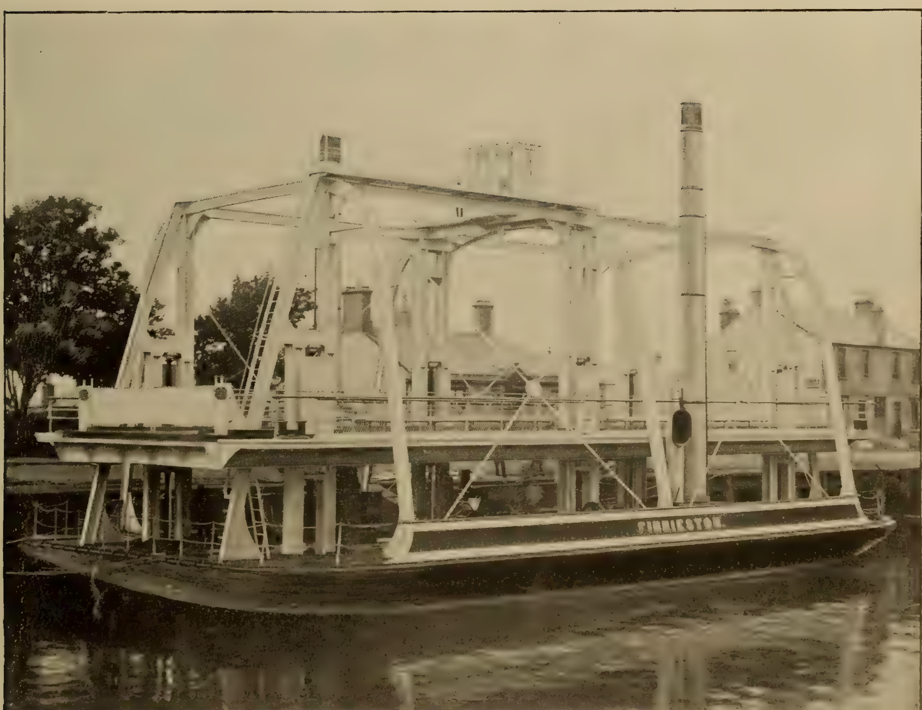
bridge, like the one of the present day. The thrust of this bridge is taken on a pile platform, which is built independent of the rest of the ferry house, and has a certain freedom of motion. The smallest detail of slips, bridges, etc., is the result of long experience and much ingenious planning. Now, however, the double decking of boats is giving rise to a new set of problems, the only solution so far having been reached by the Pennsylvania Railroad Company in their stations at Jersey City and New York. The chief advance, however, in ferry houses has not been in any new engineering features, but in the substitution of iron or steel framing for wood, in more elaborate decoration, in better provision for the safety and comfort of passengers, and in greater attention to those many small details that go to make up any successful design.

As in the ferry houses, so in the boats the changes were only additions to the old type. The boat itself remained the same in general design in New York. Elsewhere, however, other conditions produced different results. Mr. Livingston Brady, of New York, patented about 1867 a system of screw propulsion for ferryboats. Two vessels were built for use on the Mississippi, but were not satisfactory on account of the action of the quick water against the levees. The first successful screw ferryboat of which I have any information was the Oxton, built by Messrs. Simons, of Renfrew, Scotland, for service on the Mersey. She is 100 ft. long by 30 ft. beam, and her propelling machinery consists of two engines driving two shafts with two screws at each end of the boat. As shown in the illustration on this page, she makes her landings side on, this method of landing being quite general on the other side of the Atlantic.

The illustrations on pages 283 and 284 show two other boats of Messrs. Simons, who, by the way, are the most advanced designers and builders of this class of vessel in Great Britain. The peculiar raising and lowering platform on the boat Finnieston will strike Americans peculiarly. When it is re-

membered, however, that she runs on the Clyde with great differences of water level at high and low water, the necessity of some such design will be apparent. The Hutton is for service on the Thames at Greenwich. She carries her teams on the upper deck, which is floored with bridge plates and wooden block pavement. This peculiarity will be alluded to again further on. The illustrations of the St. Ignace, on pages 285 and 294, show a type of boat evolved by quite different conditions from those to which New Yorkers or our English cousins are accustomed. This vessel was designed and built by Mr. Frank Kirby, of the Detroit Dry Dock Company, for train service across the Straits of Mackinac, Mich. Her run is a long one and the ice in winter is of great thickness. To meet these conditions she is single-ended, and has two screws, one small one forward and one large one aft, each with its own engine. When ice is met, the foward screw is reversed. The quick-water breaks up the ice, and the peculiar egg-shaped form of the bow enables the boat to force her way through with little delay.

The underlying principle of the screw ferryboats plying at New York, on the North river, is a rigid line of shaft extending from bow to stern and carrying a screw at each end. There is one engine, or its equivalent, working on the crank shaft. One screw pulls the boat ahead and the other pushes her. I do not know to whom should be given the credit of first suggesting or applying this principle. As I have already said, the Oxton, built by Messrs. Simons, of Scotland, was the first ferryboat of that type, though in her there were two shafts and four propellers. Tugs on this principle have long been in use at Oboc, in Finland. In 1887 Mr. William Cowles, of New York, read before the American Society of Mechanical Engineers a paper on screw



ELEVATING FERRYBOAT FINNIESTON.

THE HUTTON.

ferryboats, in which he advocated a peculiar arrangement of the funnels, and a single engine, connected by two universal joints, with lines of shafting working the propellers at either end. At the time that Mr. Cowles' paper was read, I was working with Capt. C. W. Woolsey, superintendent of the Hoboken Ferry Company, on the drawings of a boat which subsequently became the Bergen.

The illustration on page 287 of the Bergen on the dry-dock gives a good idea of her midship section and of the arrangement of her screws and rudders. In deciding on the general plan on which the vessel should be designed, the first question that arose was as to the method in which the power was to be transmitted from the engine. Having assumed as a starting point that screw propulsion was the best, the choice lay between the following: 1. A single screw, at one end. 2. Twin screws at one end. 3. Twin screws at each end, as in the Oxton. 4. A screw at each end, and under this head (a) Cowles' system with universal joints; (b) an independent engine and shaft for each end, as in the St. Ignace (I believe that Brady's boats were of this type); (c) a single, rigid shaft, with a screw at each end.

I shall stop you a moment and ask you to step on the upper deck of a New York ferryboat. You must not expect me to ask you into the pilot house, as, unless you have a pilot's license, the law forbids it, and if we should have a collision the court may think that you "rattled" the pilot and mulct our boat in damages. Now look around and see the everyday life of the lower Hudson. There to the southward you will see an ocean tramp threading his way along. Astern are a steam lighter and a tug with a car float in tow, while a couple more tugs are hunting around for jobs, like beagles searching for a trail. The giant Campania is backing out of her berth, her monster stacks witnessing the industry of her stokers, who are now beginning to shovel coal to again lower the eastbound record. A Sound steamer is making her pier further down, while one of the steamboats bound for Coney Island is rushing down stream and an excursion tow is heading slowly for Glen Island. In between them all, steadily and surely, a dozen ferryboats are carrying their human freight to do the daily work of the great metropolis. All this is crowded into a square mile of water which itself is moving to or from the sea at two and a half miles an hour.

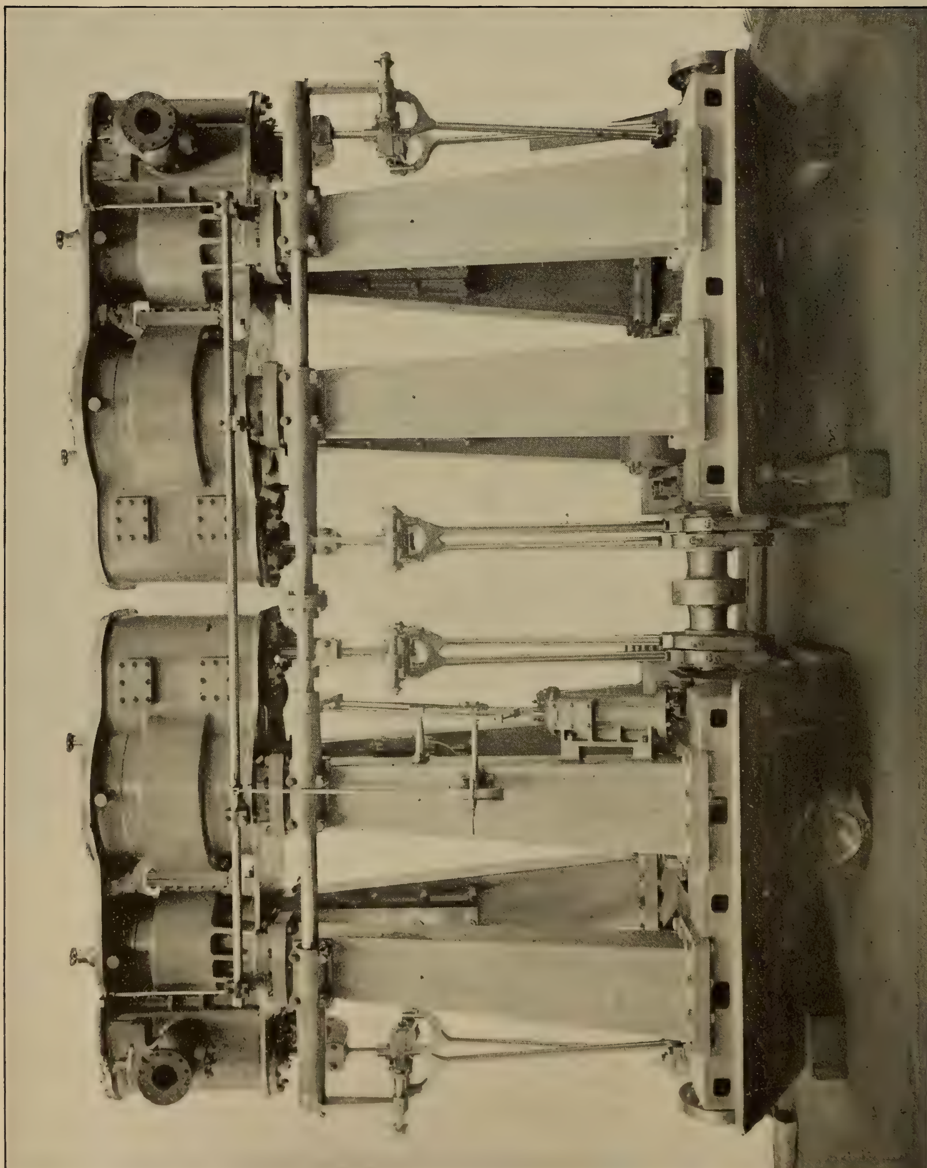
Now, think of the problem set to the

ferryman. He must carry, in safety, across this crowded harbor, with its rapid and changing currents, a large portion of the business population of one of the world's great centres of business. It is estimated that the yearly passenger trips between New Jersey and New York number 70,000,000; that the total for all New York ferries will exceed 170,000,000; that the number of boat trips equals 1,800,000, and the number of teams carried 5,000,000. All this immense traffic is carried on with remarkable safety. The lamentable accident to a Staten

THE ST. IGNACE IN THE STRAITS OF MACKINAC, MICH.

Island ferryboat, some twenty years ago, and a single collision afford the only cases of deaths from accident on record among North river ferry passengers. There have been other cases of death, but they are such as are not directly connected with the risks of the business, such as falling down companionways, being run over by teams, etc. This safety can be secured only by a combination of good discipline and management, with good boats, and good boats are those which not only can withstand the effects of a collision, but which, better still, are able to avoid it and to come uninjured out of a tight place.

You want, therefore, first of all, stopping power; after that some other qualities, such as handiness in steering, quickness in starting, and ice fighting qualities, but above all, and again, stopping power. The man who pays the bill will add economy in first cost and operation. These are the data of the designer. Every one will be perfectly content if the boat can make twelve or thirteen knots on her trial trip and hold the same number of statute miles at full speed on her route. The engineer must have an engine that he can repair quickly and cheaply, and that will do the backing when called on, and not stick on centres or churn up the water uselessly. The hull must be well shaped, so that it will steer quickly and will not sink at the bow when loaded by the head. It must be good for ice work, with easy lines and, above all, must be staunch and strong and as nearly unsinkable as skill and money can make it. As usual, both engineer and pilot want a list of qualities that cannot well



COMPOUND ENGINES OF A DOUBLE-SCREW FERRYBOAT.

be combined, or, as that "rara avis," an honest horse jockey, put it when a perfect horse was described to him and he was asked at what price he would furnish such an animal: "There never was no sich horse as you ask for."

But you are probably getting tired of all this wandering and I shall return to where I first buttonholed you, and again take up the Bergen, where we left her, that is, on the drawing board. After a careful study of all the pros and cons it seemed clear that, if it were possible to keep the vessel and the shaft in line, a single shaft with one engine and a screw at each end would be best suited to the conditions. The single screw and the twin screws at one end only would not, when they were astern, give the backing power required; besides this, the single screw would turn the vessel one way or the other when reversed, and the double screw would be exposed to danger by ice and floating wreckage. Either plan would involve a difference in steering between the ends, a fault that might at any time cause a very serious accident. The design of the Oxton offered the advantages of great handiness and good stopping, but involved exposed screws and a complication of parts.

This meant a greater first cost and increased repairs. A screw at each end would give fair handiness, good protection and backing power, and it seemed probable, as it has since been proved by experience, that the head of the boat would not fall off materially when the engine was reversed. The system, however, as a method of driving a vessel is not efficient, as the increased friction on the fore body, due to the race of the forward screw, causes a considerable increase in resistance. This has been proved by careful experiment,

THE BERGEN ON THE DRY DOCK.

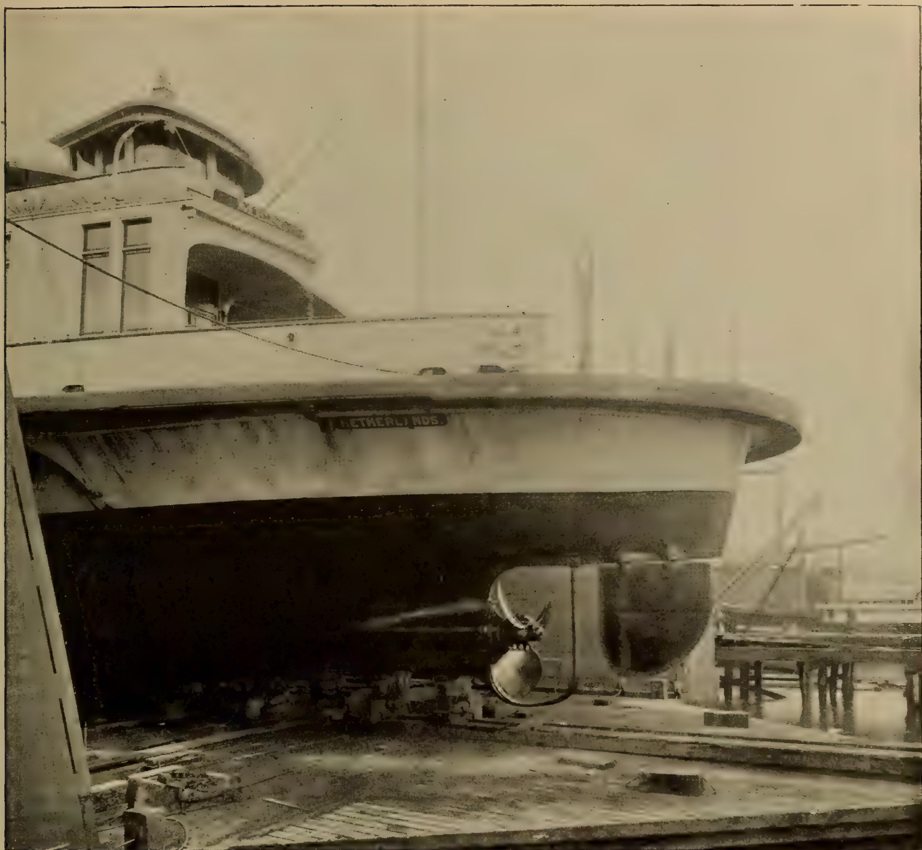
as related by Prof. J. E. Denton' in a paper on the Bergen, read before the American Society of Mechanical Engineers in 1890, and by running one boat—the Bremen—in actual service, with only one screw. I may add that the economy found did not warrant the increased risk in navigation and the delay necessary in making landings. From this point of view any of the other

systems of propulsion are preferable except Cowles', which, in this respect, is similar to that of the Bergen. The objection to Cowles' plan is the use of universal joints. If a satisfactory joint can be made, his plan would offer some decided advantages. The only remaining idea was the use of two engines, each with its own independent shaft and screw.

It would be possible with such an arrangement to run the forward screw at such a speed that its pitch, multiplied by the number of revolutions, would be exactly equal to the speed of the boat. This would then give no race and would do away with the increase in frictional resistance, but the forward engine would do no useful work and would be in the vessel merely to enable her to back quickly. Here I would again digress and repeat that every boat has to be designed for her own work, and that the design which suits New York waters may not be equally well suited for other ferries. Each route, even in the same harbor, presents different problems and demands different treatment.

ONE OF THE BERGEN'S PROPELLERS AND RUDDERS.

To secure handiness or good steering, the Bergen's screw is set a little away from the hull and her rudder is quite a distance from the screw. Her midship section is a decided V, and the shape of the longitudinal sections, water, bow, buttock and diagonal lines were carefully modeled to give screw and rudder a full supply of solid, unbroken water. It is not desirable that the ends should overhang more than necessary to secure whatever advantages are to be gained by plenty of room for rudder and screw. These overhanging ends are not nice things to plate and are sources of weakness and expense. In some of the



A DRY DOCK VIEW OF THE NETHERLANDS.

boats that followed the Bergen on other routes, a more compact arrangement was chosen. This gave the advantages of cheaper first cost, stronger structure and a closer approach to equality between the supporting buoyancy of the water and the weights to be carried. These advantages, though not to be despised, appear to me to be secured by a sacrifice of handiness and ease of shape and an increase in wetted surface. There is no doubt that each plan is best suited to certain conditions.

The principal troubles with screw ferryboats are that, in common with all propeller vessels, they are apt to steer more easily to one side than the other, depending on the pitch of the screw, and that when the engine is stopped and the vessel is forging ahead by its momentum, or is forereaching, it does not respond to the rudder. The first of these troubles ought not to cause difficulty in a well designed vessel; the second was the main fault of the Bergen. This may not seem very serious to the uninitiated, but a few trips over the river will quickly show him that some set of circumstances will soon combine to force a boat to stop her engine before she is pointed straight into her slip, and as a result she must swing while forereaching or hit the rack a more or less heavy blow. These blows mean repairs and the repairs mean delay and expense. To secure a better result, when forereaching, in the boats that followed the Bergen on the Hoboken ferries, the cut-out at the ends was increased from 11 to 16 feet, the

THE UPPER SALOON OF THE NETHERLANDS.

rudders were widened fore and aft, and the pitch of the screws was increased from 9 ft. to 11 ft. In the last boat, the Netherlands, a three-bladed propeller was used instead of a four-bladed one. These changes materially reduced the defect, but even yet the screw boats are not as good as the old side-wheelers in this respect. It is but fair to say that this is the only point in which the screw boats are inferior.

In length these vessels vary from 200 to 220 ft. and the beam, from 62 to 65 ft. over all. They form, from the standpoint of the engineer, the passenger or the decorator the finest fleet of ferryboats ever produced. That their designs will be found to admit of improvement can not be questioned, but the direction in which to look for advance is not, perhaps, so obvious as the possibility thereof. Economy in operation and simplicity in the design of the quite extensive auxiliary plant will at once suggest themselves.

The lightening of the whole structure is desirable, if possible, without sacrificing the strength necessary for the service, and in this direction a cautious breaking away from the habits and traditions of ship building should be encouraged. I have on more than one occasion pointed out the likeness between a ferryboat and a truss bridge. This likeness, suggested by a casual remark, itself naturally suggested the question, why should not the general plan of construction of these boats partake of the characteristics of both a bridge and a vessel? In order to determine which feature of each should be used, a consideration of the strains brought to bear on the structure was necessary. To get at these, curves representing the longitudinal distribution of the weights and of the supporting buoyancy were necessary. These curves, when drawn on the same base, show whether at any point the load is greater or less than the capacity of the support. Roughly speaking, the weights at the ends and middle of the vessel are in excess of the buoyancy, while the latter will be greater at a point on each end between the extremities and the midship section. If the weights were calculated for very small

sections, other unimportant points of support would appear. The conditions are, moreover, subject to a certain amount of change with every different load carried. Some of the older wooden boats illustrate these strains very clearly and practically. The line of their guards show how the ends and midship sections have gone down and how the intermediate sections have risen, thus locating the points of support and application of the load.

Returning to our idea of a bridge, we would have to design a structure to be supported at two points, each about one quarter of the length from either end, and loaded at these ends and in the middle. The chords of such a truss will be in tension and compression according to the position of the points considered, relatively to the points of support. The strength of the upper and lower chords should be nearly equal, and it must be remembered that they are the deck and bottom of a vessel as well and, as such, subjected to certain local strains and conditions to be specially provided for. As in all girders, the connections must be such as to properly transmit strains between the upper and lower members. The Netherlands' midship section shows a method of meeting these conditions. The longitudinal bulkheads are the connections between the heavily framed bottom and the corrugated deck. This deck is of bridge plates running continuously fore and aft, and thus forming the upper member of our girder, the bottom of the boat being the lower member. Our deck must carry the heaviest teams practically without bending, and the vessel's bottom must stand not only the pressure due to the head of water, but must carry the shaft without disturbing its alignment, and also support the heavy engines and boilers. The Hutton, previously mentioned, has bridge plates for decking. In her case, however, they are buckle plates, and not the longitudinal trough sections used on the Netherlands. Carrying her teams on the upper decks, the bridge plates can not be used as in the

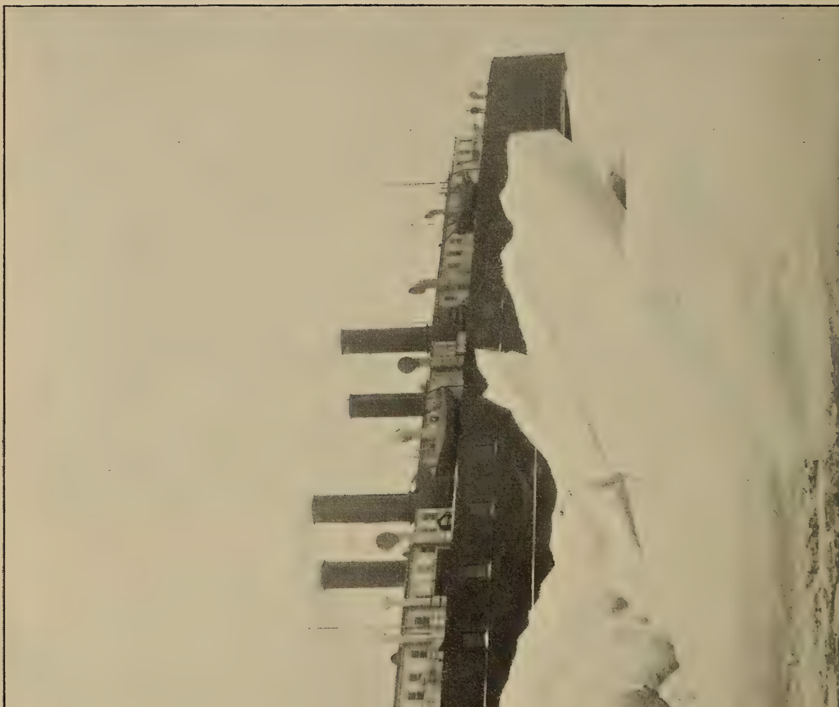
THE LOWER SALOON OF THE NETHERLANDS,

MAIN DATA OF THE NORTH RIVER SCREW FERRY BOATS THUS FAR BUILT.

NAME.	Number of Decks.		Hull.			Engine.			Owners and Route.
			L'gth.	Built by	Designed By	Type.	Built by	Designed by	
Bergen	1	1889	203	T. S. Marvel & Co., Newburgh, N. Y.	Owners	Triple 3 cyl. 18½". 26". 42" × 24"	Delamater Iron Works, New York	J. Shields Wilson, Philadelphia	Hoboken Ferry Co., Hoboken and New York
Jno. G. McCulloch	1	1891	210	Neafie & Levy, Philadelphia	Builders	Compound 2 cyl. 26". 50" × 30"	Neafie & Levy, Philadelphia	Neafie & Levy, Philadelphia	N. Y., L. E. and W. R. R., Jersey City and New York
Cincinnati	2	1891	206	S. L. Moore & Sons Co., Elizabethport	Owners	Compound 4 cyl. 2-18". 2-36" × 26"	Owners	Owners	Pennsylvania R. R. Co., Jersey City and New York
Bremen	2	1891	222	T. S. Marvel & Co., Newburgh, N. Y.	Do.	Compound 4 cyl. 2-20". 2-36" × 28"	W. & A. Fletcher Co., Hoboken, N. J.	Builders	Hoboken Ferry Co., Hoboken and New York
Hamburg	2	1892	222	Do.	Do.	Do.	Do.	Do.	Do. Do. Do.
Washington	2	1892	206	Delaware Ship Bldg. Co., Chester, Pa.	Do.	Compound 4 cyl. 2-18". 2-36" × 26"	Owners	Owners	Pennsylvania R. R. Co., Jersey City and New York
Easton	2	1893	158	Harlan & Hollingsworth Co., Wilmington, Del.	Builders	Compound 2 cyl. 16". 30" × 22"	Harlan & H. Co., Wilmington, Del.	Builders	C. R. R. of N. J., Jersey City and New York
Mauch Chunk	2	1893	158	Do.	Do.	Do.	Do.	Do.	Do. Do. Do.
Netherlands	2	1893	207	T. S. Marvel & Co., Newburgh, N. Y.	Owners	Compound 4 cyl. 2-18". 2-36" × 28"	W. & A. Fletcher Co., Hoboken, N. J.	Builders	Hoboken Ferry Co., Hoboken and New York

THE UPPER SALOON OF THE CINCINNATI.

THE LOWER SALOON.

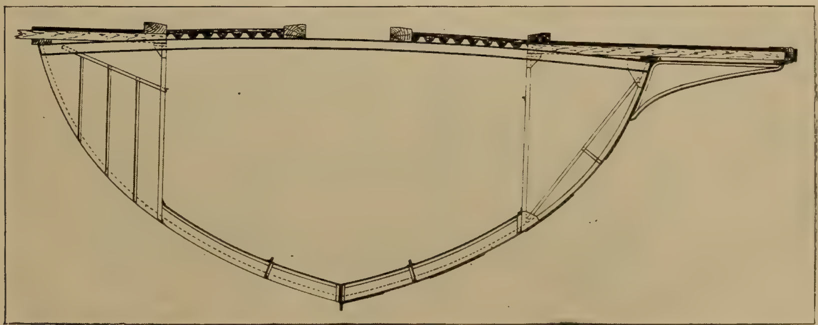


THE ST. IGNACE BREAKING THROUGH ICE THREE FEET THICK.

A TYPICAL MODERN FERRY HOUSE.

Netherlands, but with the wooden block pavement they seem to supply an admirable surface for vehicle travel. The wooden sheathing, commonly used in this country under covered gangways, does not give the most satisfactory results.

An important subject, and one which has received too little attention, is that of balancing the engines of these boats. Not only is this a promising field in the way of comfort to passengers, but in economy as well. It is possible to locate the points of maximum and minimum vibration by moving from one seat to another when under way, reading a newspaper the while, and noting the differences in the apparent motion of the sheet before your eyes. In one whose life, like mine, has been greatly spent in more or less intimate connection with these boats, they



MIDSHIP SECTION OF THE NETHERLANDS.

Some Trial Trip Figures of Hoboken Ferryboats.

NOTATION.	Orange Single Cylinder Diameter = 46". Stroke, 10".	Bergen Triple Expansion 18½" × 27" × 42". Stroke, 24".	Bremen Double Compound 20" × 36". Stroke, 28."	Netherlands Double Compound 18" × 38". Stroke, 28".
	Trial Trip.	Trial Trip.	Trial Trip.	Trial Trip.
Boiler pressure in pounds per square inch above atmospheres	23	114	98	100.8
Vacuum in inches of mercury	27	27	26	25.8
Average revolutions per minute for time engine was tested	22.9	144	115	119.0
Average horse-power of main engine	490	700	778	737.13
Ratio of expansion from point of cut-off	2.1	9	10.3	13.20
Steam per hour per H. P. of main engines for all purposes	27.5	21.7	20.7	19.88
Ditto for engine and circulating pumps	----	18.3	18.6	17.35
Ditto for main engine	27.2	18.3	18.1	16.85
Speed in statute miles per hour	11.5	12.5	12.4	12.4
Per cent of slip	26.0	13.0	13.3	14.8
Boiler evaporation per pound of coal from temperature of hot well and actual pressure	8 6	9 2	8.8	8.5

awaken an interest that it may be difficult for some to understand. To such a one they represent not merely an ugly form of boat, doing, more or less faithfully, an uninteresting and prosaic duty; they are not merely a drudge without life or character; each of them has an individual life and character of her own, each has her own moods and fancies, and each becomes the object of those peculiar personal feelings that ships of all kind, no matter how noble or humble they be, have always awakened in those who handle them.

In closing, therefore, I hope that I may be pardoned for a perhaps overdrawn summary of the virtues of my special pets, the North River screw boats. The nine boats built thus far are, as I have already said, the finest fleet of ferry craft the world has yet seen. They can and do carry their passengers at a speed, with a degree of comfort, safety and regularity unequalled before their day; the thickest ice and the heaviest gales have not thrown them behind their schedule; the small number of accidents they have met and the comparative immunity of their passengers from injury in those that have happened, attest their safety, while their unquestioned popularity is the best evidence that they render the public good and acceptable service.

LIBERTY ENLIGHTENING THE WORLD, IN NEW YORK HARBOR.

MODERN LIGHT-HOUSE SERVICE.

By Edward P. Adams, C. E.

First Paper.

BEACON LIGHTS to guide the wave tossed mariner to a safe harbor must have been almost coeval with the earliest commerce. There is positive record that light-houses were built in ancient times, though few evidences now remain to us from old writers or in crumbled ruins. This is not strange, for light towers, never the most stable architectural form, were exposed to the storms of sea and war.

The Greeks attributed the first light-houses to Hercules, and he was considered the protector of voyagers. It is claimed by some that Homer refers to light-houses in the XIX book of the Illiad,

"So to night-wandering sailors pale with fears
Wide o'er the watery waste a light appears,
Which on the far-seen mountain blazing high
Streams from lonely watch-tower to the sky."

Virgil mentions a light on a temple to Apollo, which, visible far out at sea, warned and guided mariners. The Colossus at Rhodes, erected about 300 B. C., is said to have shown a signal light from his uplifted hand.

The oldest towers known were built by the Sybians in lower Egypt. They were temples also, and the light-keeper priests taught pilotage, hydrography, and navigation. The famous tower on the Isle of Pharos, at Alexandria, built about 285 B. C., is the first light-house of undoubted record. This tower, constructed by Sostratus, the architect, was square in plan, of great height and built in offsets. An open brazier at the top of the tower contained the fuel for

EDDYSTONE LIGHT-HOUSE.

the light. At Dover and Boulogne, on either side of the English Channel, were ancient light-houses, built by the Romans. But the light-house at Coruña, Spain, built in the reign of Trajan, and reconstructed in 1634, is believed to be the oldest existing light-house.

At the present time the light-house system of Western Europe leaves little to be desired. The New World has taken its lesson from the Old, and welcomed commerce by its beacon lights. The famous Cordouan Tower of France, at the mouth of the Geronde, in the Bay of Biscay, was completed in 1611, in the reign of Henry IV., and after a lapse of 280 years it is still considered the finest light-house in the world, though it has been increased in height. "One is filled with profound admiration on finding himself in the presence of this majestic monument, rising with such boldness from the bosom of the sea."

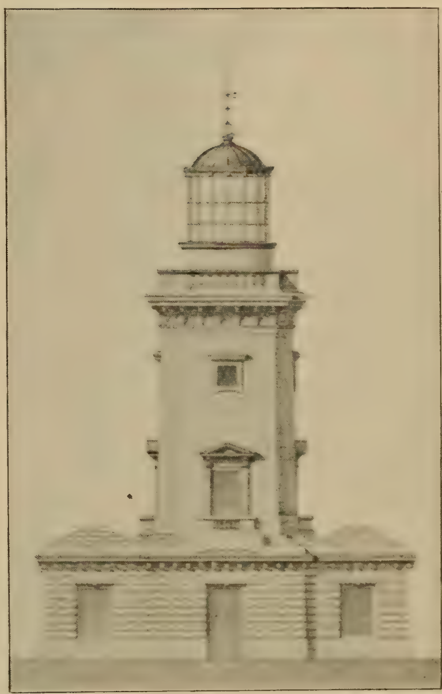
The erection of Eddystone light-house of Plymouth, England, completed in 1759, made a new era in the construction of such buildings. The fifty courses of granite were so dovetailed and fastened together that the tower was almost as rigid as if cut out of solid rock; but, strong as it was, it became necessary to take it down and rebuild it on a neighboring rock, as that on which it was founded was weakened by constant beatings of the sea. The masonry of the light-house was 76 feet, and the top of the lantern, 93 feet above the foundation.

Bell Rock light-house, the next English light-house of a similar nature, is one hundred feet high, and was finished in 1810, at a cost of $300,000. The light-house on Skerryvore Rock, off the west coast of Scotland, which cost,

with the harbor for the tender, $435,-000, was first illuminated in 1844. Another of this nature is the light-house on Bishop Rock off Scilly, one hundred and forty-five feet high, and cost $182,-500. Wolf Rock light-house off Lands End, Cornwall, Wales, is the latest great British work, and both in its structure and its illumination it combines all the refined improvements. The foundation was commenced in March, 1862, and the light-house completed in July, 1869. In the first season only eighty-three hours of work could be done, and the whole time occupied in the building was equal to about one hundred and one working days. The cost was $313,630. The great distinction between the later towers and their predecessors is that the stones of each course are dove-tailed together laterally and vertically so that the use of metal or wooden pins are needless. This method was first used at Hanois Rock, Guernsey.

On the coast of France many remarkable light-houses have been built. At the present time, probably the most complete system of light-houses is possessed by that country. Cape de la Hève, near Havre, at the mouth of the Seine, is marked by two towers with lights of the first order. The first towers were constructed in 1777. At first coal was burned for light. A lantern consisting of sixteen spherical reflectors, with two or three lamps each, was added to each tower in 1781. Changes, due to the encroachments of the sea, and improvements in illumination followed. These towers have since been modified to receive electric apparatus for the new system of "lightning-lights." The light-house of Triagoz, of the third order, is built upon an isolated rock. There are three rooms above the ground floor, built with cloistered arches and fire-places. This structure was commenced in 1861 and finished in 1864 at a cost of $58,600. The light-house of Walde is an example of a successful method used in sand or loose material. It is built upon screw piles, well braced, holding the light-house above the reach of the sea. This method was first used by Alexander Mitchell in the foundation of the English light-house on Maplin Sand at the mouth of the Thames. The light-house of Heaux de Bréhat was built about three miles from the most northerly end of Brittany on a partially submerged rock where the currents at times ran eight knots an hour. It cost $106,365, exclusive of the lantern and illuminating apparatus.

Still more difficult was the building of the foundation of the light-house of

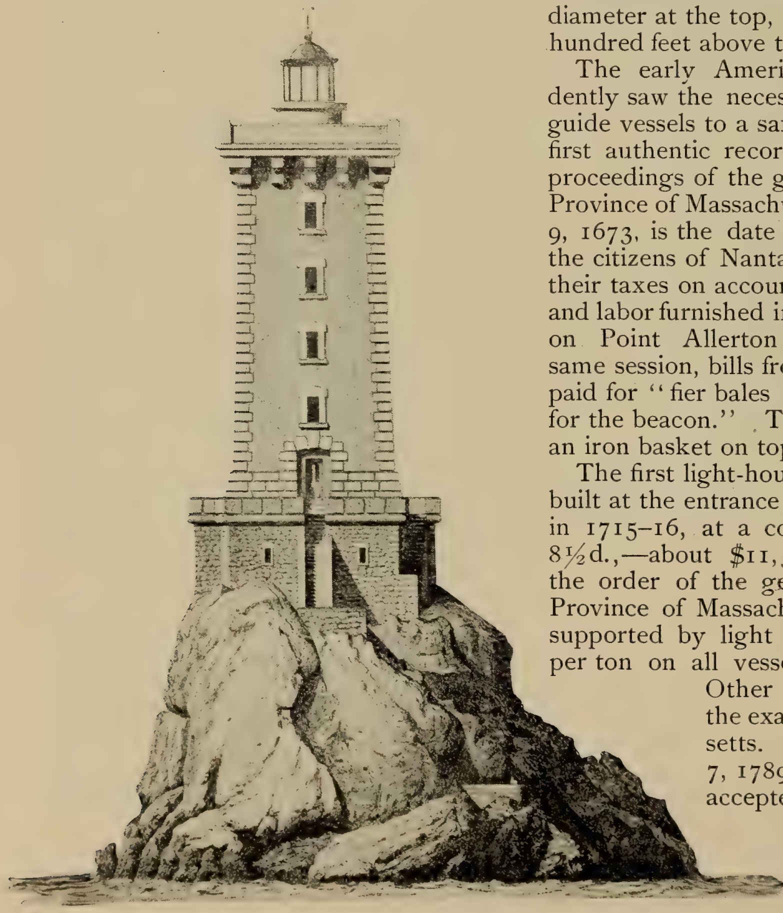


ONE OF THE LIGHT-HOUSES OF LA HÈVE, FRANCE.

Ar-men, eight miles westward of the island of Sein, on the northwest coast of France. Commenced in 1867, it was not finished until 1881. At first the workmen, wearing life-belts, had to lay upon the rock "working with feverish activity, the waves constantly sweeping over them." This great work was planned by M. Leonce Rêynaud, director of the light-house service of France. "It was carried on under the greatest difficulties," writes Major Heap in his "Ancient and Modern Light-Houses,"

"and too much praise cannot be given to the brave sailors and Breton workmen who insured the success of an enterprise, bolder, and more rash than any preceding undertaking of a similar nature."

One more European light-house well deserves mention, because it was the first light-house, erected at a long distance from land, which does not rest on a rock foundation. This light-house is Rothersand in the North Sea, Holland, near the mouth of the Weser. The history of its construction, which extended over seven years, from 1878 to 1885, of its first failure and final success, is exceedingly instructive. To build the foundation a caisson of boiler iron, thoroughly braced, was sunk in the sand to a depth of seventy-three feet below low water, then filled with concrete and masonry to about mean sea level. On this foundation was built a masonry tower with an iron shell, trumpet shaped at the base, which is 34 feet 8 inches in diameter, and 17 feet in diameter at the top, which is about one hundred feet above the water.



THE LIGHT-HOUSE OF TRIAGOZ, FRANCE.

The early American colonists evidently saw the necessity for beacons to guide vessels to a safe anchorage. The first authentic record of this is in the proceedings of the general court of the Province of Massachusetts Bay. March 9, 1673, is the date of a petition from the citizens of Nantasket for lessening their taxes on account of extra material and labor furnished in building a beacon on Point Allerton; and during the same session, bills from Nantasket were paid for "fier bales of pitch and ocum for the beacon." They were burned in an iron basket on top of the beacon.

The first light-house in America was built at the entrance to Boston Harbor in 1715–16, at a cost of £2,285 17s. 8½d.,—about $11,500. Erected by the order of the general court of the Province of Massachusetts Bay, it was supported by light dues of one penny per ton on all vessels except coasters. Other colonies followed the example of Massachusetts. By act of August 7, 1789, the United States accepted possession of title to the light-houses on the coast, and agreed to maintain them thereafter. There were eight light-houses at that time, and to-day there are light-houses on the same sites. These are Portsmouth Harbor Light, Boston Light, Gurnet Lights, near Plymouth; Brant Point Light, on Nantucket; Beaver Tail Light, Rhode Island; Sandy Hook Light, at the entrance of New York Harbor; Cape Henlopen Light, Delaware, and Charleston (S. C.) Main Light.

BOSTON LIGHT. THE FIRST LIGHT-HOUSE BUILT IN THE UNITED STATES.

When these lights came into the possession of the United States, they were placed under the direction of the Secretary of the Treasury. During the establishment of the office of Commissioner of Revenue, from 1792 to 1802, and from 1813 to 1820, the superintendence of lights devolved upon that office. From July 1, 1820, to 1852, Mr. Stephen Pleasanton, who was the fifth Auditor of the Treasury, was known as the general superintendent of lights. During this time the number of lights was increased from 55 to 325 light-houses and light-ships. As the result of investigation abroad and several reports to Congress, the act of June 30, 1852, was passed, by which the Light-House Board was organized as it now exists. In accordance with the provisions of this act, the President appointed two officers of the Navy of high rank, two engineer officers of the Army, and two civilians of high scientific attainments, with an officer of the Navy and an officer of the engineers of the Army as secretaries, to constitute the United States Light-House Board. The Board is attached to the office of the Secretary of the Treasury, who is its president, and under his superintendence it discharges all the administrative duties relating to the construction, illuminating, inspection, and superintendence of light-houses, light-vessels, beacons, buoys, and other sea marks, the security of foundations of existing works, procuring illuminating and fog-signal apparatus, supplies and material of all kinds for building and rebuilding and keeping in repair buildings, vessels, and buoys of the United States. The Board elects from its own number a member to act as chairman in the president's absence; meets quarterly, and as much oftener as is necessary; with the approval of the Secretary of the Treasury, it makes rules and regulations for securing an efficient, uniform and economical system of administration; and under its orders are prepared by its engineer officers of the Army, all plans, drawings, specifications, and estimates of cost of all illuminating and other apparatus, of construction and repairs of towers and buildings. It secures by public contract all material for construction and for repairs. The members of the Board receive no pay for their services, other than their regular pay in the Army, Navy or Civil Service. They, as well as all others in the light-house service, are prohibited from having any interests in any light-house contract.

The chairman with the Naval Secretary and the Engineer Secretary form the executive committee of the Board. The members are divided into committees on finance, location of light-

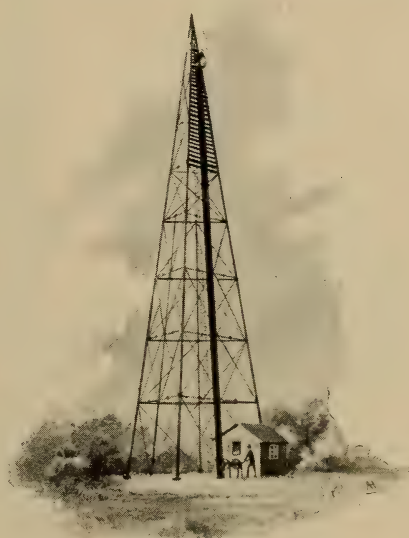
MINOT'S LEDGE LIGHT, MASSACHUSETTS.

houses, engineering, floating aids to navigation, lighting and experiments. That one of its members most expert in each particular branch is placed at the head of the committee having charge of that branch. An inspector who is a Navy officer, and an engineer officer from the Army are assigned to each district, and usually serve three years—sometimes six years—before they are transferred. One engineer may have charge of two districts. The inspectors, under the direction of the Board, are charged with the maintenance of the lights and floating aids to navigation, and the discipline and payment of the light-keepers. In the same way the engineers are charged with building the light-houses and other structures, with keeping them in repair, and with the purchase, setting up and repairs of illuminating and fog-signal apparatus. Both make regular and special reports to the Board, acting always under its direction, and the Board makes a full report annually to Congress.

The regular publications of the Light-House Board are: 1. "Lists of Lights and Fog-signals," with illustrations,—one for the Atlantic and Gulf Coast, one for the Northern Lakes, including the Canadian Lights, and one for the Pacific Coast, including the lights of British Columbia; 2. "List of Beacons, Buoys and Day-marks,"—one for each of the first eight Light-House Districts, one for the Northern Lakes, and one for the Pacific Coast; 3. "Annual Report of the Light-House Board to the Secretary of the Treasury." The appendices to these reports, occupying often a third of the volume, include many valuable illustrated reports of construction, maintenance and experiments.* In 1791, the United States expended for its Light-House Establishment a little over twenty-two thousand dollars; in 1890, three and a half million dollars were appropriated; and the total expense for the hundred years was ninety-three and a quarter million dollars.

The first light-keeper in this country whose appointment is on record was George Worthylake, who was appointed custodian of the light-house at Little Brewster, Boston Harbor, in 1716, at £50 per year by order of the general court of the Province of Massachusetts Bay. When the Federal Government had assumed charge of the Light-House Establishment, the appointment of keepers was made by the President, and quite a number of commissions bear the signature of George Washington or Thomas Jefferson, who took great interest in light-house affairs. As the number of light-keepers increased, their nomination was made by collectors of customs, who were the local superintendents of lights, but the appointment was made by the Secretary of the Treasury. This usage still holds, but the nomination of the Collector is forwarded to the Light-House Board, whose indorsement procures for it favorable or adverse action. The appointment, however, is temporary. It continues only until the candidate has been examined, after which, if he passes, a full appointment is given him. Otherwise, he is dropped from the service.

The appointment of light-house keepers is restricted to persons between the ages of eighteen and fifty, who can read, write and keep accounts, are able to do the required manual labor, to pull and sail a boat, and have enough mechanical ability to make the necessary



REAR BEACON, PARIS ISLAND RANGE, S. C.

minor repairs about the premises, and to keep them painted, whitewashed and in order. After three months of service, the appointee is examined by an inspector, who, if he finds that he has the qualities needed at that especial station, certifies that fact to the Light-House Board, when, upon its approval, the full appointment is issued by the Treasury Department.

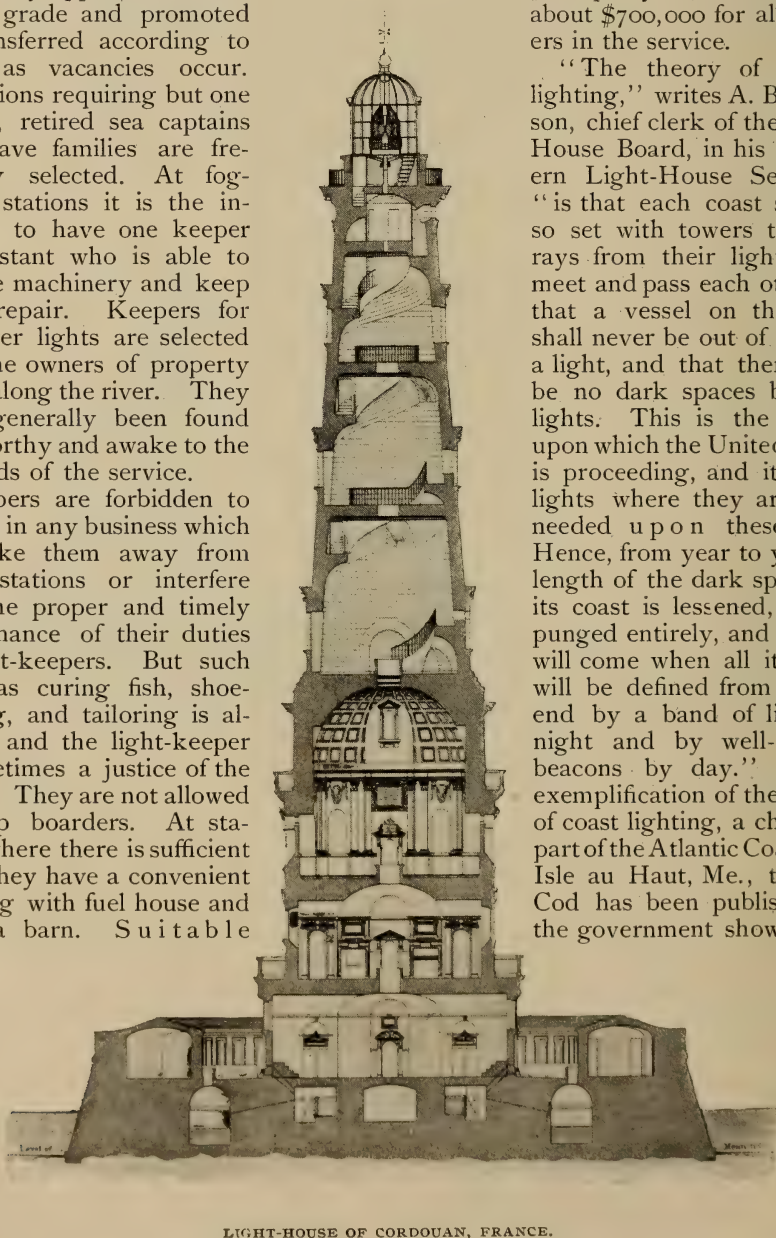
Only one grade of keeper is recognized by law, but practically they are divided into a number of grades with pay ranging, with a few exceptions, from $350 to $820. The lowest salary is $100 and the highest is $1000. At

* In this paper I have drawn freely from Johnson's "The Modern Light-House Service," The other books consulted on this subject are Heap's, "Ancient and Modern Light-Houses," Eliot's "European Light-House System," "Barnard on Light-Houses," Findlay's "Light-Houses of the World," and Rèynaud's 'Illumination and Beaconage of the Coast of France." The latter, finely illustrated, was translated and printed for the use of the Light-House Establishment.

first and second order shore lights, there are two light-keepers. A second assistant is required where there is a steam fog signal in connection with the light. At isolated stations another assistant is added. At a few of the most exposed stations there are three and even four assistant keepers. Keepers are usually appointed to the lowest grade and promoted or transferred according to merit as vacancies occur. At stations requiring but one keeper, retired sea captains who have families are frequently selected. At fog-signal stations it is the intention to have one keeper or assistant who is able to operate machinery and keep it in repair. Keepers for the river lights are selected from the owners of property living along the river. They have generally been found trustworthy and awake to the demands of the service.

Keepers are forbidden to engage in any business which will take them away from their stations or interfere with the proper and timely performance of their duties as light-keepers. But such work as curing fish, shoemaking, and tailoring is allowed, and the light-keeper is sometimes a justice of the peace. They are not allowed to keep boarders. At stations where there is sufficient land, they have a convenient dwelling with fuel house and often a barn. Suitable boats are furnished to stations not accessible by land. A kitchen stove is supplied, also a little coal and sufficient kerosene for lights, and good libraries of about thirty volumes are furnished, and exchanged from two to four times a year. The amount appropriated for the salaries of keepers is at the rate of $600 per year, amounting to about $700,000 for all keepers in the service.

"The theory of coast lighting," writes A. B. Johnson, chief clerk of the Light-House Board, in his "Modern Light-House Service," "is that each coast shall be so set with towers that the rays from their lights shall meet and pass each other, so that a vessel on the coast shall never be out of sight of a light, and that there shall be no dark spaces between lights. This is the theory upon which the United States is proceeding, and it plants lights where they are most needed upon these lines. Hence, from year to year the length of the dark spaces on its coast is lessened, or expunged entirely, and the day will come when all its coast will be defined from end to end by a band of light by night and by well-marked beacons by day." As an exemplification of the theory of coast lighting, a chart of a part of the Atlantic Coast from Isle au Haut, Me., to Cape Cod has been published by the government showing the



LIGHT-HOUSE OF CORDOUAN, FRANCE.

limit of illumination of lights and of ordinary audition of fog-signals. This chart indicates clearly how much more complete is the chain of lights than the chain of fog-signals for the safe guiding of the mariner. This also shows why there has been an earnest call for a light-ship about six miles east of Boston Light.

The aids to navigation which are under control of the Light-House Board are of three general classes :—1. Light-houses and lighted beacons ; 2. Beacons, buoys, stakes and other day marks ; 3. Fog-signals, including whistling and bell buoys. Each of these classes should cover the approach to the whole coast and large lakes, and all the broad part of the navigable rivers to form a complete system of light-house service. The number of these aids to navigation maintained by the Light-House Establishment, June 30, 1893, are given in the following table :—

AIDS TO NAVIGATION

Maintained by the Light-House Establishment on June 30, 1893.

Electric lights	4
First order lights	56
Second, third and three-and-a-half order lights	82
Fourth, fifth and sixth order lights	529
Lens lanterns, range lanterns, reflector lights and tubular lanterns	2,030
Light vessels in position	33
Light vessels for relief	6
Electric buoys	20
Gas buoys	2
Total lighted aids	2,756
Fog signals operated by steam or hot air	114
Fog signals operated by clockwork	189
Whistling buoys in position	64
Bell buoys in position	90
Other buoys in position, including pile buoys and stakes in fifth district, and thirty buoys in Alaska waters	4,315
Day or unlighted beacons	419
Total unlighted aids	5,191
Steam tenders	20
Steam launches	8
Sailing tenders	2
Light keepers	1,139
Laborers in charge of river post lights	1,503
Other employees, including crews of light-ships and tenders	821

Previous to 1840, the light-houses on the New England coast of the United States were either conical towers of rubble stone masonry, or wooden frame towers upon the roofs of light-keeper's dwellings. In 1849, the construction of six difficult light-houses was entrusted by Congress to the Topographical Engineers of the Army. Capt. W. H. Swift rebuilt Black Rock beacon in Long Island Sound, where three stone beacons had been overthrown, erecting an iron pile beacon, 34 feet above low water on a stone platform bedded in concrete. This structure is still standing. Capt. Swift also erected a well braced pile structure 70 feet high at

AN OHIO RIVER POST LIGHT.

Minot's Ledge, in the open sea off Cohasset, Mass.; but this was destroyed by the storm of April, 1851, the nine 8-inch iron piles being broken or twisted off near the rock. Brandywine Shoal light-house, in Delaware Bay, lighted in 1850, was the first built in the United States on Mitchell's screw piles. The broad helicoidal flange of this pile bored like an auger into sand or mud, so as to form a broad foundation to which the pile structure was fastened. This light-house, which is 46 feet high and still in good condition, was designed and built by Maj. Hartman Bache. It was surrounded by an ice-breaker of thirty connected 5-inch screw piles, the whole

DETROIT RIVER LIGHT STATION.

costing $64,800. Carysfort Reef light-house, Florida, 112 feet high, costing $105,000; Sand Key light-house, whose focal plane is 121 feet above the foundation, costing $101,500, and Sombrero Key light-house, on the Florida Reefs, about 50 miles east of Key West, 148 feet high, costing $120,000, were built on the same general plan. In the last-named light-houses, the 12-inch wrought-iron foundation piles go ten feet into the rock, and rest on cast-iron disks 8 feet in diameter. There are now more than seventy screw pile light-houses varying in detail and size, mostly in Southern waters. Thimble Shoal Light, off the entrance to Hampton Roads, Va., is typical of this construction. Fowey Rock Light, on the extreme northern point of the Florida Reefs, is a typical screw pile light-house in the open sea. It is built of iron and rests on nine iron piles, driven about ten feet into the live coral rock.

Light-houses constructed of cast-iron plates have lately come into general use for dry foundations. Among the most prominent of these iron towers are those at Cape Canaveral, Florida, built in 1868, 150 feet high; at Bolivar Point, Texas, built in 1872, 120 feet high; at Hunting Island, S. C., built in 1875, 120 feet high; and the tower at Cape Henry, which is 165 feet high. The shell of the tower is composed of cast-iron panels, weighing about 1200 pounds each, of the same size in each section. These panels vary in thickness from 1½ inches in the lowest section to ¾-inch in the highest section. There are flanges on the inside to connect the several tiers of plates, and the plates of each tier with each other by bolts. A broad flange about three feet wide, at the base of the first tier, rests on the concrete foundation to which the tower is fastened by anchor bolts. The whole tower has a lining of bricks. Hunting Island light-house, a typical tower of this kind, cost $102,000. Iron skeleton towers, like that at the Southwest Pass of the Mississippi, are built where the soil affords an inadequate support for a regular tower and where cheapness is required. The foundation consists of a

grillage of timber resting on piles and covered with concrete. On this are secured the iron sockets supporting the eight outside shafts and the central tube containing the stair-case. As these towers offer so little resistance to the wind, and are cheap to build, they are found to well meet the purpose intended. The rear light of the Paris Island range, at Port Royal, S. C., is a very economical skeleton iron structure, built in 1880. A locomotive head-light, with powerful parabolic reflector, is hoisted at night on a track to its place at the apex of a triangular beacon, by machinery worked in the oil house. The whole structure, 132 feet high, completed and lighted, cost $12,000.

There are many light-houses of brick and iron like those at St. Augustine and at Cape Hatteras. In the former seven flights of spiral stairway make each half a revolution of a spiral, and the eighth, a whole revolution. This light is of the first order, 150 feet high, and cost about $100,000. The present Minot's Ledge light-house was almost the first important structure erected by the Light-House Board. In the words of General Barnard, "it ranks, by the engineering difficulties surrounding its erection and the skill and science shown in the detail of its construction, among the chief of the great sea-rock light-houses of the world." As described by General Alexander, "it was a more difficult work of construction than either the Eddystone, the Bell Rock, or the Skerryvore." A good part of the foundation of Minot's Light was below low water. A perfectly smooth sea, a dead calm and low spring tide were necessary to enable the beginning of the work to be made. The Board gave to the plan and its execution its freshest and best powers, and the combined energies of all its members. The tower was designed by General Totten, Chief of Engineers, U. S. Army, and built by Capt. B. S. Alexander according to the plans of Gen. Totten. The ledge was cut into steps, and the tower was built of Quincy granite, the blocks being dovetailed together and fastened with iron bolts and Portland cement. It was commenced in July, 1855, and finished in June, 1860, and cost, including the keeper's houses on shore, about $300,000.

Similar in structure to that on Minot's Ledge are the light-houses on Spectacle Reef, Lake Huron, and on Standard's Rock in Lake Superior. They are of the same height (one hundred feet) and of the same cost. The light-house on Spectacle Reef was planned and built by Gen. O. M. Poe, who was Gen. Sherman's chief engineer in his march to the sea. Tillamook Rock light-house, in Oregon, like Matinicus Rock Lights, Maine, is a typical structure on a high isolated and greatly exposed rock. The Detroit River light-house is a typical wooden caisson foundation ; while Fourteen-Foot Bank light-house is a typical iron caisson foundation for the open sea, like Rothersand Light in the North Sea. A still more difficult work will be the building of a light-house on Outer Diamond Shoal, off Cape Hatteras.

FIRST STATIONARY STEAM ENGINES IN AMERICA.*

By F. R. Hutton, M. Am. Soc. M. E.

A LETTER was recently addressed to the Secretary of the American Society of Mechanical Engineers, asking the following questions :--"What, when, and where was the first steam engine in America (not locomotive and not steamboat engine)?" Reflection brought out the point that this was a question on which, as far as known, the historical text-books were silent, or at best indefinite, though it has at least a historic interest, and concerning which much information might doubtless have been transmitted verbally, and would be in the possession of persons now living. It would obviously be more difficult to secure this information as time went on.

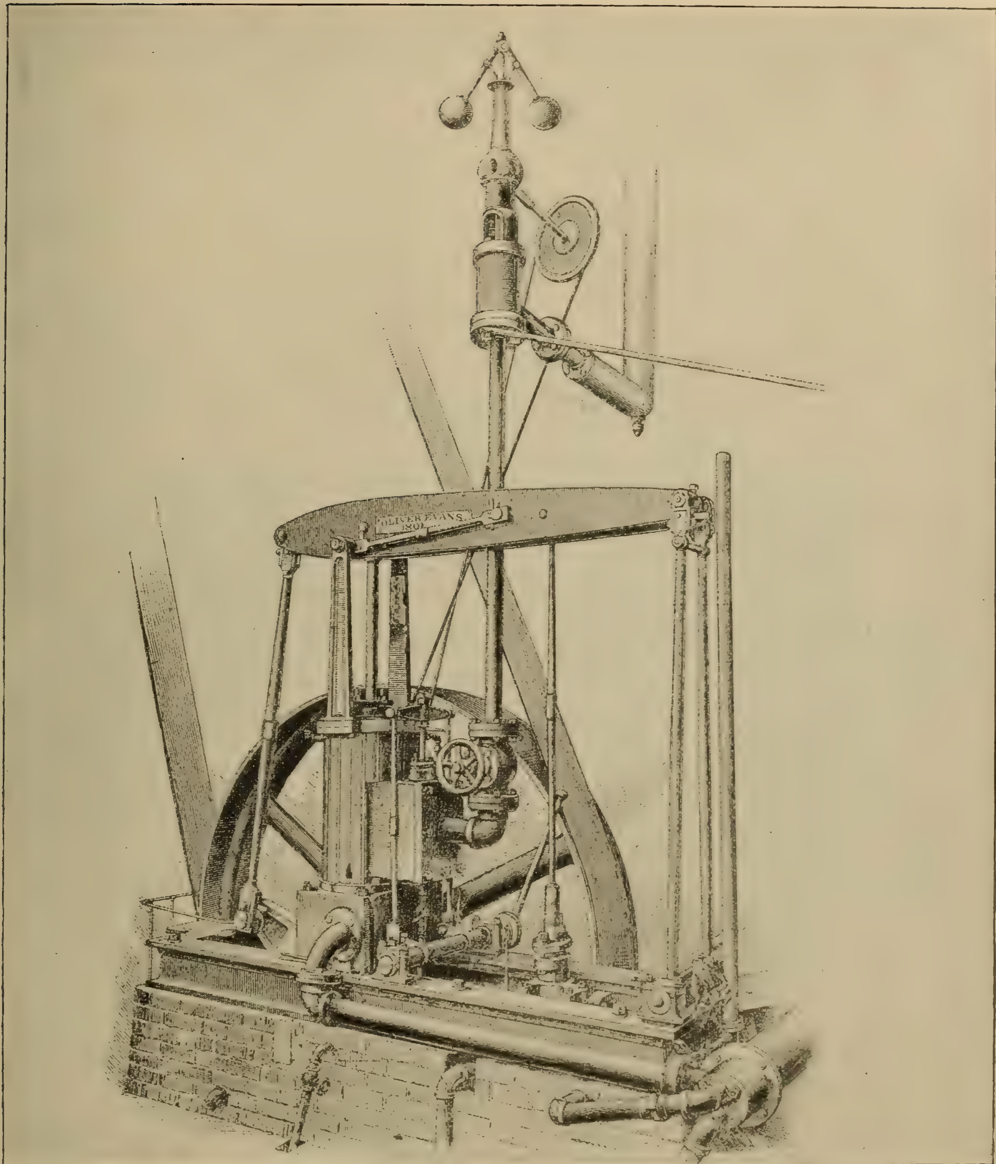
The locomotive engine in this country has been quite thoroughly written up in the memorials of the Stevens family, in the papers of Mr. Horatio Allen, and most fully of all in the exhibits in the Transportation Building of the Columbian Fair in Chicago, 1893. The history of navigation by water has again been very thoroughly reviewed in the lives of Robert Fulton; in pamphlets detailing the early Stevens experiments, and in the History of the Growth of the Steam Engine by Professor R. H. Thurston, member of this Society. While there is a regrettable silence and lack of record as to the development of engineering for water propulsion during the period of its most active growth, from the beginning of the century up to the period of the War of the Rebellion, yet the first beginnings are matters of pretty full record. James Watt died in 1819. The period of his greatest activity runs from 1774, when the partnership with Boulton was begun, up to the first year of the present century, when the two partners turned the business over to their sons and retired from active business. There could not have been any well known constructor of steam engines in the neighborhood of New York city in 1807, when Fulton prepared his Clermont, or he would not have sent to Boulton & Watt, in England, for his cylinder.

In Pennsylvania, Oliver Evans, in 1800 or 1801, built an engine "six inches diameter of cylinder and eighteen inches of stroke of piston, which he applied with perfect success to driving a plaster mill." * Oddly enough, he called this engine the "Columbian" engine. It then occurred to the writer to make individual inquiry among those conversant with such matters, with most interesting results, which it is the purpose of the remainder of this paper to record. Mr. W. F. Durfee writes: "In the last year of the eighteenth century there were but three steam engines in the United States. One of these was used (probably built as well) by Oliver Evans in Philadelphia for grinding plaster; another was an imported engine, built by Hornblower and brought to America by his son, and put at work for driving the Schuyler copper mine in New Jersey. The third engine is said to have had a locus in New England, but just where, I have never been able to discover."

The first engine referred to above is the same one mentioned by Professor

* Presented at the Montreal meeting (June, 1894), of the American Society of Mechanical Engineers.

* History of the Growth of the Steam Engine. R. H. Thurston.

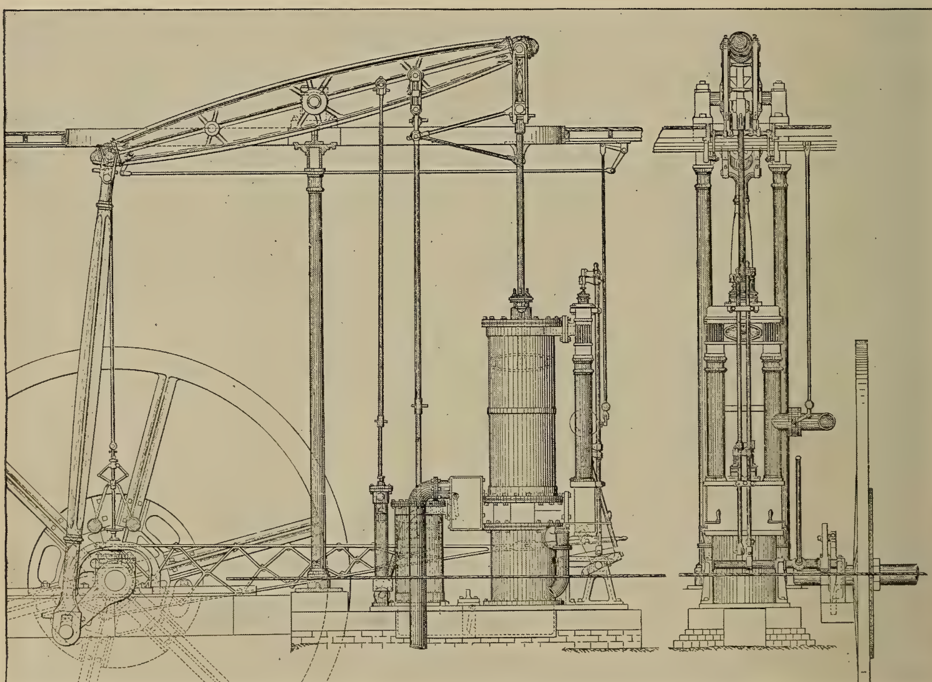


AN EVANS "GRASSHOPPER" ENGINE OF 1801.

Thurston. The second one was for a mine at Belleville, near Newark, and all that appears to remain of the engine is its cylinder, which was imported from England in 1753. The boiler is said to have been of copper, upright, 8 or 10 feet in height, and of equal diameter. It will be remembered that this cylinder was an object of interested inspection on the occasion of a visit of this Society to shops of Watts–Campbell & Co., in Newark, N. J., December, 1886. It was not bored, but was cast surprisingly round, and used as it came from the foundry.

Mr. Samuel Webber writes :—" I

find in looking up my old memoranda, that the 'second steam engine in Providence, R. I. of 24 horse-power, was built by Oliver Evans, for the Providence Bleaching, Dyeing and Calendering Company, in 1814.' The next date I have is a steam cotton mill at (Olneyville), Providence, in 1831, but whether this was the old 'Providence Steam Mill,' which was one of the first, if not quite the first one, I am not now sure. Your correspondent must look to some Rhode Island authority to settle this point. I have also a note of a steam mill in Fall River in 1831, but cannot say what one, possibly the 'Metacomet;' their first mills were all 'water-power.' North of Boston the first one was the 'Bartlett Steam Mill,' of Newburyport, in 1838, followed by 'James,' in 1843, then came the 'Ocean,' of the same place in 1846, and the 'Portsmouth' of the same date."



A 90 HORSE-POWER BEAM ENGINE, BUILT IN 1815 BY JAMES WATT. NOW AT SAVANNAH, GA.

Believing that in a manufacturing centre like New England the textile industry would be among the first to call for the steam engine, in pursuance to the letter of Col. Webber, inquiry was made at the hands of Mr. C. J. H. Woodbury, and from his letter in reply the following quotation is made:—"I also wrote to the venerable Thomas J. Hill of Providence, a man nearly ninety years old, and still in active business in the manufacture of cotton machinery, and he gave a reply which confirmed my impression, but gives many othe details. He says that the first cotton mill run by steam that he knew of was the Steam Cotton Mill of Providence, R. I., built by Samuel Slater, Wilkinson, Howe & Tompkins of Pawtucket, and Benjamin and Charles Dyer of Providence, during the years 1828 and 1829, and was started under the supervision of David Whitman with 4300 spindles. They made at first sheeting with number 38 warp and number 45 filling, the warp being Sea Island Cot-

ton, costing sixty-eight cents (68c.) a pound and the filling Upland Cotton costing nineteen cents (19c.) a pound. The mill changed ownership on account of dull times in 1829, and Samuel Slater took it with Trott & Bumstead & Fessenden of Boston, as partners. The mill was not successful at first and changed superintendents quite a num- of times and made but little money until 1838."

Mr. Charles W. Copeland, in reply to an inquiry, writes a letter full of most interesting details, from which the following quotations are taken: "My father built the first engine for power purposes in, I think, about 1826 or 1828. My father [Daniel Copeland] had the largest machine shop in Connecticut, and the only one in that State which built steam engines and boilers; there was a shop in Boston by a man, I think named Ashcraft, who built small engines; I remember that he had an application to build a 20 horse-power engine, and he declined because it was too large for him, but he would build for him two engines of 10 horse-power each, to work together. When my father took his first engine to build, it was for a blowing engine for a foundry in Hartford, and my father went to New York to get men to go to Hartford to work on it, as there were no men in Hartford who had any experience in that class of work. I worked on the engine when building, also when being erected; I do not know what afterward became of it. About the time of which I am writing, a Mr. James (the same who put the first locomotive on the Harlem railroad) built a small engine for a coffee and spice factory; it had two cylinders, in fact a compound engine, only the cylinders had both the same bore and one cylinder exhausted into the other; Mr. James claimed that this tended to economy of fuel—I differed from him, and I remember we had quite an argument."

As the history comes up to more modern days, the uncertainty, of course, diminishes, and history becomes more full and complete. Mr. Washington Jones, of Philadelphia, consulting authorities under his hand, gives the following references:—From an abstract of a lecture delivered at the Franklin Institute, November 20, 1885, on "Oliver Evans and his inventions," by Coleman Sellers, Jr.:—"In 1803 Mr. B. H. Latrobe, in his report to the American Philosophic Society, describes five or six engines then at work in the United States, and among others mentioned a small engine erected by Mr. Oliver Evans." This was doubtless his first engine, that which he started the year previous to Mr. Latrobe's report. Mr. Jones, also quoting from a historical sketch of Oliver Evans, by Rev. George A. Latimer, adds that "the cost of the Evans engine of 1801 was $2000, and that during the next year he became the first regular steam engine builder in the city of Philadelphia, at the Mars Works."

Another Evans engine was sent to New Orleans for a steamer, but according to Professor Thurston, "financial difficulties and low water combined to prevent the completion of the steamer, and the engine was set at work driving a saw mill, where, until the mill was destroyed by fire, it sawed lumber at the rate of 250 feet of boards per hour." Mr. Jones also quotes from a history of Philadelphia by Scharf and Westcott, Vol. I., page 517, "Manufactures are growing rapidly; of calico printing establishments near Philadelphia there were Howson's at Kensington, Stewart's at Germantown, and Thornburn's at Darby; the three turning out 200,000 yards in 1803." Mr. Jones adds, "two at least of the above-named must have been driven by steam engines."

Other Evans designs in Philadelphia were the Grasshopper engine at the Burtis cotton spinning mill in Philadelphia, whose design stamps it as being either of Oliver Evans' make or of Rush & Muhlenburg, his sons-in-law, partners and successors. The mill building was closed and the engine dismantled about 1866. Mr. Jones also met a non-condensing engine in the distillery of Alexander Young's Sons in Philadelphia, which was built by

Hyde & Flint, of that city, and had been in constant use for sixty years. It is of the overhead beam type, steam cylinder, 12 by 36, with a long slide valve.

The general appearance of these Evans engines is made apparent from the cut on page 309, reproduced from The Iron Age. It was built by the I. P. Morris Company, of Philadelphia, in 1845, the date upon the beam being that of the Evans patent. It remained in constant service in the smith shop of the above company until 1893, when it was presented to the University of Pennsylvania. The only repair necessary was the reboring of the cylinder from its original 8½ to 10 inches and the patch put on the upright of the parallel motion, which was done by Mr. Jones himself. The stroke is 18 inches.

A similar inquiry also brought from Professor Sweet the suggestion that at the Brush Electric Light and Power Company of Savannah, information could be had concerning one of the very old Boulton & Watt engines which was still running in that city. The side and end elevations given herewith are reproduced from a blue print furnished by Mr. T. P. Keck, of that company, showing the engine as restored by Messrs. John Rourke & Son, of that city. The legend on the blue print reads :—

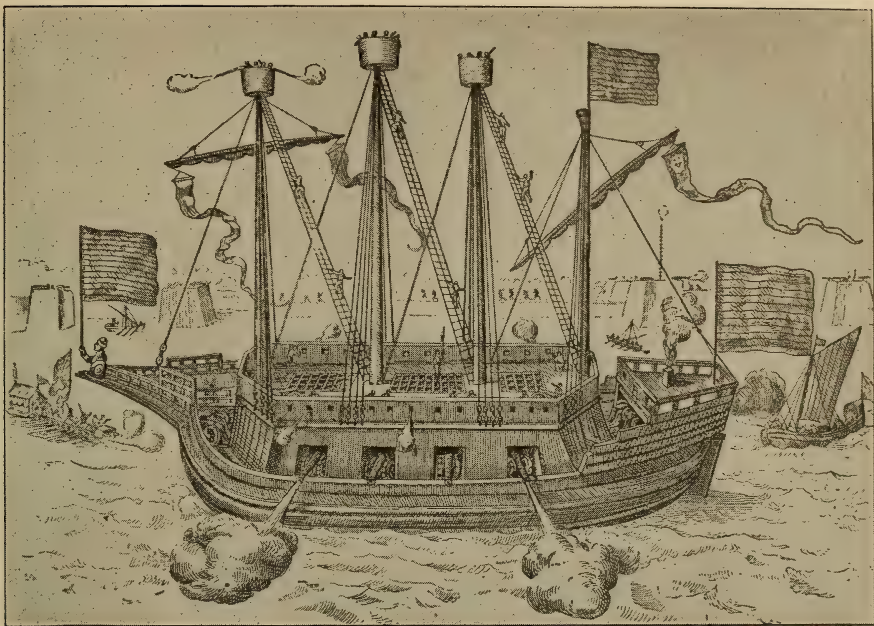
"Ninety horse-power beam engine built in 1815 by James Watt, Lancashire, England. Cylinder 31 in. diameter, stroke of piston 72 in., 18 revolutions per minute with 8 lbs. steam pressure, common jet condenser and 24 in. air pump, feed pump worked from beam to supply boilers, the crank, shaft, and connecting rod are made of cast-iron. This engine was brought to Savannah and erected at the rice mills of Messrs. McAlpin & McInnis. It has been working regularly since and was put in good repair by John Rourke & Son, Novelty Iron Works, Savannah, Ga., August, 1891."

THE EARLIEST IRON-CLAD.

By R. H. Thurston.

THE modern iron-clad probably had its origin in the very beginning of the century and in the brain of that great statesman and engineer, Col. John Stevens. He, in 1812, or earlier, conceived the idea of constructing an iron-plated vessel of war with a saucer-shaped hull, propelled by screws so arranged that direction as well as forward motion could be given by them. The battery was to be of the heaviest ordnance of the time, and the plating heavy enough to resist the shot of similar guns at short range. The main purpose of the ship was the defense of our harbors, and the plan of action was to moor the ship by a chain leading down through the bottom of the vessel at its centre, and to spin the craft around this centre, firing gun after gun as it came in line of fire, thus anticipating the later Timby turret which, in turn, was the gem of the modern "monitor" iron-clad. Such a vessel was actually built, a half century later, by the Russian government, and the "Popoffska" is the contemporary representative of the first Stevens battery.

The metal ram-bow was familiar in the days of the ancient Greeks. The inscriptions on stone, unearthed in the the Piræus in 1834, gave us the information that three-banked war vessels were in use several centuries before the Christian era, and that four banks of oars came into use about 431 B. C. The sizes and proportions of these vessels were given in great detail in this ancient record, and, among other data, the weight of iron required for the ram.



THE DUTCH IRON-CLAD FINIS BELLI, 1585.

It is an interesting and curious fact that the old Greeks and Romans, as well as the old Scandinavians, had before the dawn of the historial period, apparently, learned the best forms for their ships, and had adopted the very proportions adopted by Nature herself when endeavoring to secure high speeds. This proportion was about seven or seven and a-half times the breadth of beam for the length of the ship on the water-line. Some of the largest vessels are said to have been 420 feet long and 57 feet in breadth of beam. Docks at Zea were 20 feet wide and over 150 feet long.

The first iron-clad actually laid down was the Stevens battery of 1842, designed by Robert L. Stevens, in consultation with his father, Col. John Stevens, and under a contract with the United States government for "a war steamer for harbor defense, shot and shell-proof, to be built principally of iron." It was to be 250 feet long, 40 feet beam, and of equal depth, and was to be driven by engines of 900 horse-power. Later, in 1844, the dimensions of the then partially constructed ship were enlarged; and a vessel of 415 feet length on the keel, of 48 feet beam, and 33.5 feet deep was begun still later under a contract with the government, made in that year. The plating was to be 6.75 inches in thickness, and the engine-power was to be 8674 indicated horse-power. The ship was never completed. The first iron-clads actually built and employed in warfare were those of the French navy, of 1854, the "Devastation," the "Lave," and the "Tonnage," which did effective work in the Crimean war, beside the ships of the British fleet. The French built the "Gloire" in 1858, and the British ship "Warrior" was ordered in 1859. Iron clads have, since that date, been, admittedly, the only really formidable war vessels. Without them, it is doubtful whether the operations of our own navy, during our civil war, could have been successful. This is the authentic history of the iron-clad of our day. According to some authorities, the Dutch were the first in the modern period of history to build an iron-clad, and it is said that, during the siege of Antwerp by the Spaniards

in 1585, the people of that city built an enormous flat-bottomed vessel, armored it with heavy iron plates, and thus constructed what they regarded as an impregnable battery, which they named "Finis Belli." Unfortunately, the vessel got aground before fairly in action, and fell into the hands of the enemy. It was held by Alexander of Parma to the end of the siege, as a curiosity, but was never employed by either side in any action.

It is not at all certain, however, that any modern engineer or inventor can claim to have had the first conception of an iron-clad ship. Curiously worded sentences in early literatures of all nations indicate, often, the possession of modern ideas at a time when it was utterly impossible to carry them into effect, in consequence of the inability of the mechanics of the time to perform the work. The earliest of these which I have as yet noted is to be found in the "sagas" of Thorstein, a supposed pirate viking ancestor of mine, which were some years ago published by Professor Rasmus B. Anderson, and his colleague, Bjarnason. These sagas are Icelandic, dating back five hundred years or more, and relate to the deeds of the old sea-kings of a thousand years ago. The "sagas" were traditional and transmitted only by verbal communication, from generation to generation, until finally reduced to writing, probably, in the twelfth or thirteenth century. The Thorstein sagas are, historically, introductory to the Fridthiof tales. But it is supposed that the latter were true semi-mythological stories based upon popular tradition, and, very likely, upon some exact statement of an original fact ; the former are romances in which it is impossible to say what is the proportion of probable truth, and what of imaginary story. These Icelandic legends are too little known ; they are full of the spirit of Scandinavian poetry, and, legendary as they are, and imaginative as they largely must be, they still contain, undoubtedly, many hints of the life and thought and character of our wild and warlike ancestors.

In this old story of Thorstein, I find the following bit of possibly authentic history of navies. The story goes that Viking, son of Vifil and Eimyrja, is poisoned by drinking from the magic drinking horn of Dis, sister of Harek and daughter of Kol ; the former of whom had been killed by Viking in a duel, receiving a thrust from the irresistible sword Angervadil. The sea-king, become the leprous victim of Dis, sails for home, and meets, on his way, another powerful viking, Halfdan, who becomes his friend and endeavors to aid him in his effort to, in turn, secure vengeance upon Dis. Of this great captain the tradition says :

"Halfdan had a great dragon (war ship) called 'Iron-Ram,' and all of this ship which stood out of water was iron-clad ; it rose high out of the sea, and was a very costly treasure."

Viking recovered and lived to fight many days, Halfdan remaining a faithful ally, and his eldest son, Thorstein, lived and fought after him, until he, too, died at a great age, also leaving many sons and daughters ; but no more is said of the "Iron-Ram," and it is to be presumed that the treasure of their kingdoms was insufficient, in those days, to continue the construction of such costly war vessels. The story is nevertheless a most interesting and suggestive one. Whether iron-clads were built, or not, by the Scandinavian vikings, Thorstein's legend at least proves that the idea existed, and that the invention of the iron-plated ship is due to our forefathers of centuries, and possibly of more than a thousand years ago.

REFRIGERATION FROM CENTRAL STATIONS.

W. Wilberforce Smith.

THE superiority of refrigeration obtained by mechanical processes, as compared with that obtained by melting ice, appears in the facts, that by it more intense cold may be secured, that any desired degree of cold may be maintained with perfect uniformity, that a dryer atmosphere is secured in the refrigerating box or room, that the inconvenience of frequently replenishing ice bunkers and the slop and dirt attendant upon this work are avoided, that the annoying uncertainty of ice supply and variability in its price are avoided, that space in the rooms or boxes to be cooled is economized by substitution of a coil of pipe on walls or ceiling for the bulky ice bunker, and that this refrigeration can be employed for many purposes and places where ice cannot be used at all. Added to all this is the fact, of paramount importance, that where much refrigeration is required the cost of a machine and its operation is far less than the cost of ice sufficient to do an equal amount of work.

These advantages have proved so great in practice that every brewery, packing house, cold storage warehouse or other establishment requiring a large amount of refrigeration, contains its individual refrigerating plant. Where consumption amounts to ten tons or more of ice daily, the question of economy will be almost invariably decided in favor of the machine; if less than ten tons be required, the cost of a machine and its operations may exceed the cost of ice sufficient to do a similar amount of work. In many such cases the superior quality of the refrigeration obtained, its cleanliness, reliability and convenience, or the requirement of more intense cold than ice will produce, secures the adoption of the machine. Therefore, small machines are frequently found on ship-board, in hotels and apartment houses, and in many manufactories. But most of the ice gathered from rivers and lakes, or made in factories, is not consumed by the few who require large quantities, but by the many who, severally, require less than ten tons a day.

The effort to bring this superior refrigeration within the reach of small consumers has taken two directions,—the production of small and inexpensive automatic machines, and a system of supply of the refrigerant from central stations. The first has failed hitherto, because the balance of constantly varying pressures, temperatures, strength of solution, etc., is too complex a matter for purely automatic regulation. Without constant skilled attention the machines work unsatisfactorily, while the relatively high cost of plant, fuel and cooling water, in operating on a small scale, defeats economy.

A method of distribution from central stations by flasks and tank wagons, often suggested as practicable, was thoroughly tried some years ago in St. Louis, and demonstrated an inevitable financial failure. This method comprised the distilling of liquid anhydrous ammonia from aqua ammonia at a central station and its distribution to consumers, as carbonic acid gas is supplied to the proprietors of soda water fountains. The flasks were attached to the consumer's box and their contents allowed to pass through a regulating valve into an expansion coil placed

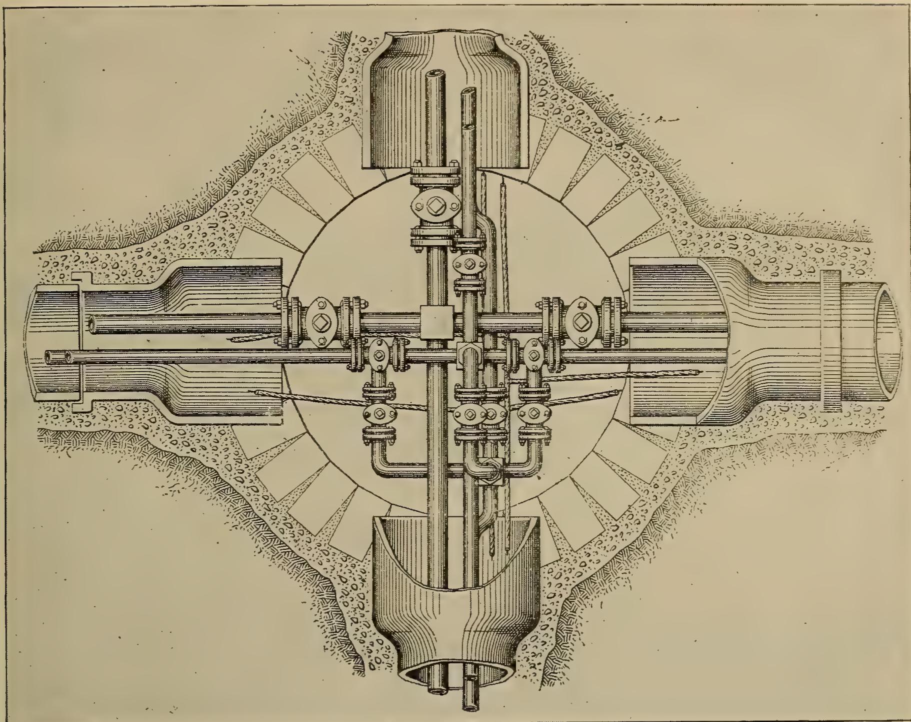
where refrigeration was to be effected, and thence, as a gas, into a receiving tank, where the gas was absorbed in weak aqua ammonia. Upon the next visit of the delivery wagon, the emptied flask was replaced with a filled one, the strong aqua ammonia was pumped from the reservoir into a tank on the wagon, to be returned for redistillation, and the reservoir was refilled with weak aqua ammonia from the central station. Thus the material was not lost. What was delivered separately as anhydrous ammonia and weak aqua, came back, combined, as strong aqua.

REFRIGERATING COILS FOR MEAT PRESERVATION.

The scheme was scientifically correct and had remarkably good equipment, including much apparatus of special and excellent design. It worked to the entire satisfaction of the customer, but proved unprofitable to the company. They erred by overestimating the refrigerating power of a given amount of ammonia and by underestimating the amount of cartage involved in this method of delivery. A pound of liquid anhydrous ammonia has, in practice, the effect of little more than four pounds of ice. It must be delivered in steel flasks weighing nearly as much as their contents, and these flasks, when empty, must be returned to the station, so that, in delivering 100 pounds of anhydrous ammonia, there is nearly 300 pounds of cartage. The 100 pounds of anhydrous ammonia require for absorption, at summer temperature, 500 pounds of weak aqua, which must be carted from the station, while 600 pounds of strong aqua must, obviously, be carted back to the still. Therefore, to do the work of little more than 400 pounds of ice, the company did nearly 1400 pounds of cartage and made two trips. They were, therefore, at a disadvantage as compared with the ice man, and, inasmuch as the cost of delivery was the chief item in the expense of both parties, could not succeed in competition.

After a season's business, the so-called "fountain and absorber" system was abandoned; but it had served important purposes. It had made known to customers the superior quality of refrigeration obtained from ammonia, and to the company, the feasibility of adapting this refrigeration to a multitude of purposes, individually very small, but, in the aggregate, very important; and it had shown to the inventor that the precise problem to be solved was that of economical distribution.

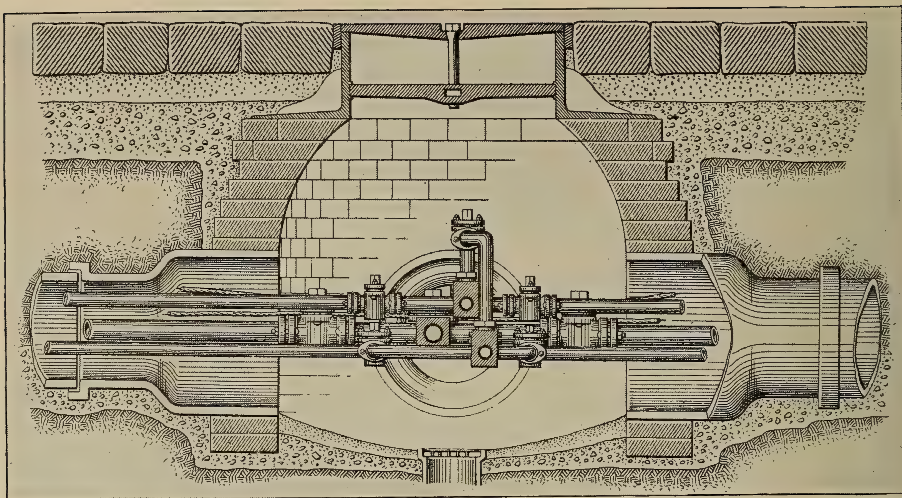
It may readily occur to one that the brine circulating system by which, as is well known, cold is carried throughout some great breweries, might be ex-



SECTIONAL PLAN OF A MANHOLE AT A STREET INTERSECTION OF A REFRIGERATING PIPE LINE.

tended through a city. A little calculation shows, however, what some have learned by costly failure, that, aside from the difficulty of supplying different temperatures to different customers, the cost of large mains and branches and their insulation, and the frequent repair because of corrosion, there must be in such a system, despite the best possible insulation, a constant and fatal loss of power by absorption of heat from the earth. In fact, brine circulation would refrigerate, more or less perfectly, its entire circuit, street mains and all, while the expense of pumping so large a volume of liquid through miles of pipe, and at so swift a rate as to furnish something better than warm water to customers last reached on the circuit, would blast all hope of profitable operation.

Attention was narrowed down, therefore, to the direct expansion system. This was known to work successfully through a long circuit, producing varied temperatures as required at different points. Its efficiency would suffer nothing by reason of high temperature surrounding street mains and pipes outside the refrigerated chambers, and the bulk of liquid in circulation would be very small. But the most extended use of direct expansion hitherto had been always under one management; the engineer controlling the generating plant was also in control of the consumption and could maintain a balance between the two parts of the system. It was foreseen that, with consumers scattered throughout a city and having all manner of needs, the demand upon the central station might vary widely and suddenly and without warning; that, in miles of piping, occasional breaks might occur, and that there must be openings, from time to time, to make new connections or to alter service already established. It would not do to shut down the entire system, thereby discontinuing the service to all



VERTICAL SECTION OF A MANHOLE.

customers, whenever such need arose. The devices invented and employed to meet these requirements constitute the new and indispensable features of the refrigerating system which companies at St. Louis and Denver are employing Adjustment to the irregular load upon the street line is accomplished by a three-fold system of large storage reservoirs, one for weak aqua ammonia, which receives and absorbs the gas as it returns from the street mains, and, as its contents become of required strength, discharges into a second reservoir of strong aqua ammonia, from which the still is supplied. The third reservoir receives anhydrous ammonia from a still through the condenser, and supplies it to the street line, according to the needs of customers. The capacity of these reservoirs is such that the service may continue for hours without the action of the still. The entire machine is in duplicate or triplicate as to its several parts, so that it is possible to shut off any part without interrupting the absorption of the continual return from the mains, or the delivery of anhydrous ammonia continually to the line in the street.

It will be understood by those familiar with ammonia refrigeration that the machine employed on the street pipe line is of the absorption type and they will readily see, also, why this kind of machine is preferred. For the general reader a very concise explanation may be desirable. Ammonia under atmospheric pressure boils at – 28 degrees Fahrenheit, and, at ordinary temperatures, is kept liquid by a pressure of ten or twelve atmospheres. In the process of refrigeration, anhydrous ammonia, compressed to liquid form, is allowed to escape very slowly through a minute valve into a comparatively large pipe, called the expansion coil, where, relieved of pressure, it expands to a gaseous form and, in doing so, absorbs heat from its surroundings, leaving them cold. The cycle of operations is completed by the recovery of this gas, and its recondensation by pressure, in a vessel surrounded by cooling water to remove the latent heat given out in the process of condensation. The action in the expansion coil, or, in other words, the refrigerating work of the machine, is the same in all systems.

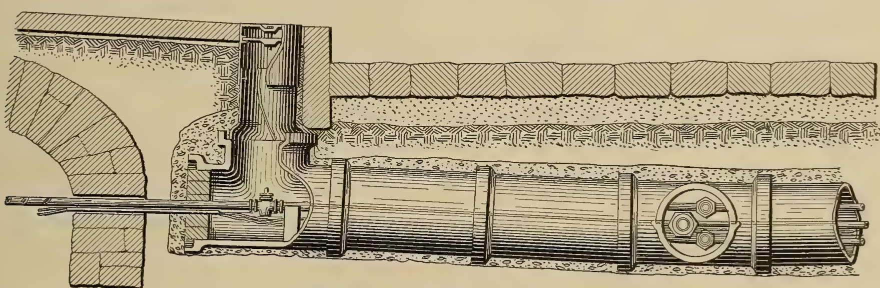
In the process of recovering the gas and again reducing it to liquid form, two very different methods are employed, known as the compression method and the absorption method. In the compression machine, the latent

heat of the returning gas is squeezed out of it by powerful mechanical pressure in a pump whose cylinder, as well as the condenser into which the pump discharges, is surrounded by cooling water to carry off this heat. The compression pump is a very delicately constructed engine, and suffers seriously if its work be irregular. Now, the return from the street mains, as has been said, is extremely irregular, and inasmuch as the compression system admits of no considerable storage of the return gas, the return feed to a compressor employed on street line work would necessarily be very irregular, and under these conditions the machine would work imperfectly and speedily wear out.

In the absorption system, storage of the return gas is effected by taking advantage of the very great affinity of ammonia for water. The gas returning from the expansion coils is absorbed by weak aqua ammonia. The strong aqua ammonia thus formed is pumped into a still where the process of distillation develops pressure under which the gas, expelled from the liquor, is reduced to liquid form and deprived of latent heat when it passes to the condenser,—a coil of pipe cooled by the constant application of cold water. No disadvantage whatever results from irregularity in the flow of return gas to the absorber. The strong aqua formed is easily stored and, although its quantity varies continually, it is supplied to the still at a uniform rate.

A modification of the ordinary expansion system, equally vital to practical success in general distribution, was the invention of the vacuum line. This is a third pipe added to the two ordinarily employed for sending out anhydrous ammonia and receiving the expanded gas. It is connected with both these pipes at convenient intervals throughout their entire length to and from the customer's box and, by proper adjustment of cocks, can be used to exhaust, or serve as a by-pass for, any section of either of them, whenever circumstances may require it. Four years of experience in Denver and St. Louis have demonstrated the indispensability of both the reservoir system and the vacuum line, and the perfect success of this solution of the problem of distribution.

The street mains are placed at any convenient depth, usually about four feet, below the surface of the earth. There is first laid a lower half-section ot vitrified sewer pipe, carefully bedded in concrete and placed upon a grade to secure drainage in case of accidental influx of water. Suspended within this, upon saddles of wood, earthenware or iron, which hold them firmly in position, are, first, the liquid line, which is an iron pipe, ordinarily one and one-quarter inches in diameter, to convey anhydrous ammonia, under an average pressure of 150 pounds to the square inch; second, the return gas main, from two to three inches in diameter, through which the ammonia, after being expanded in the refrigerating coils of the customers' boxes, will be drawn back to the central station, under a pressure of from one to two atmospheres; third, the vacuum line, usually one and one-quarter inches in



SECTION OF A CONDUIT AND SERVICE BRANCH.

diameter, through which the contents of any section of the pipes may, upon occasion, be drawn back to the central station by the vacuum pump, or which may be used as a substitute for either of the other pipes ; and, in addition to these pipes, are laid such electric wires as may be necessary for the control of valves and the transmission of signals between the central station and points along the system.

When the pipes have been thoroughly tested for leaks, the upper half section of the vitrified conduit is placed in position and securely cemented. This arrangement gives the greatest security and endurance to the pipes and, with the specially devised fittings, has proved so successful that, in four years, since the service was established at St. Louis and Denver, there has been necessity for repair of but a single leak in each city.

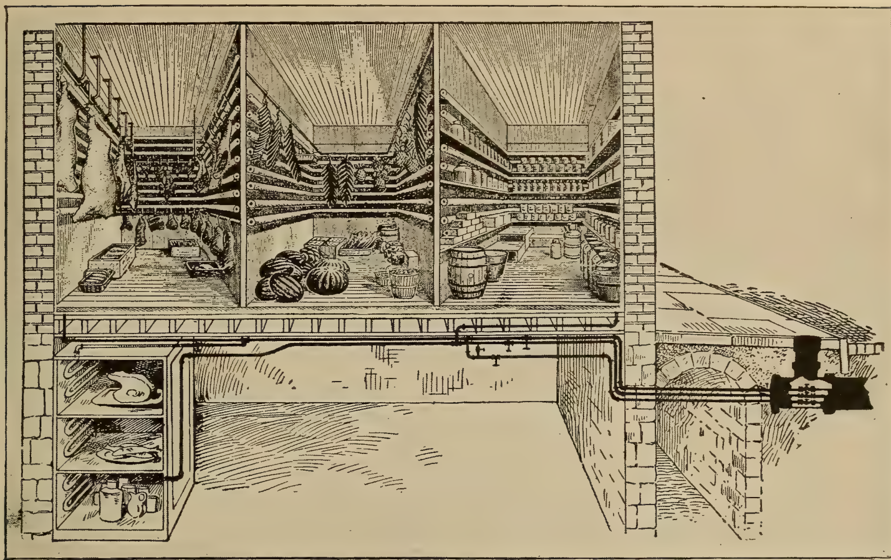
At street corners, or other convenient points, are placed man-holes, giving access to the pipes for purposes of inspection and for adjustment of the cocks by which the vacuum line is made to serve as a by-pass for the liquid line or return gas line. At frequent intervals along the street mains, branches to the sidewalk are laid in a similar manner, but of smaller dimensions. The pipes which they contain are furnished with valves, which can be operated at a stop-box, placed at the edge of the sidewalk, so that it is not necessary to enter a customer's building in order to shut him off from the service. The pipes and wires pass beneath the sidewalk, like gas or water pipes, and are continued to the walls of the refrigerating box. The flow of ammonia is controlled by a valve placed just outside the box, which may be operated by hand or by electric connection with the central station. A thermostat is placed within the box, and is so adjusted as to keep the temperature within any desired limits. In many cases no larger variation than one degree is permitted.

An excellent exhibit of the possibilities of the street pipe line service is found in the home of the Denver Club, which is situated nearly a mile from the central station. In the basement of the building is a miniature ice factory in which 500 pounds of ice for table use are frozen daily from purified water, and near it is an ice-cream freezing box. In the bar-room on the floor above, a case under the counter is kept at proper temperature for the cooling of glasses and bottles in frequent use, and the wines stored in an adjoining room have also about them an unvarying coolness. On the floor next above, the three pantries, for meats, for vegetables and fruits, and for general stores, are kept permanently each at its own temperature; thus, in a building which the ice man never visits and in which no one needs to understand or give himself a care about the mysteries of artificial refrigeration, six different degrees of temperature have been decided upon for as many places and purposes, and these temperatures are maintained the year round without variation, and at a fixed and moderate price.

An arrangement for different temperatures within more limited space is seen in a box cooled by connection with the street line at St. Louis. It has four compartments, each having a temperature different from the others. In one, the proprietor places water which freezes and furnishes him with ice to crack and serve with drinks; another holds a bath in which he cools his "steins" for beer; in another, bottles are placed to acquire a temperature to the consumer's taste, and in yet another compartment meats and other viands are kept.

Among the customers of the St. Louis company are brewers who know the value of artificial refrigeration in their business, and have secured depots upon the street pipe line conveniently placed for distribution to retail dealers. By night, when the air is cool and the streets are clear, the beer is hauled from the breweries on the outskirts of the city and speedily placed in storage, where the temperature is the same as that maintained in the vaults at the brewery.

In one of the St. Louis restaurants which the enterprising owner has deco-



SECTIONAL VIEW OF REFRIGERATING PIPE CONNECTIONS IN A BUILDING.

rated in a manner suggestive of the polar regions, pipes upon the walls are connected with the street line, so that in sweltering summer he can turn on the cold and defy the dog days. An atmosphere twelve degrees below the temperature out of doors has an enticing coolness.

Another example of the varied applications of the system, to be seen in a cafe window daily, is a display of eatables upon a heavily frosted table. This attraction is secured by making for the top of the table a shallow closed tank, completely filled with brine, through which are passed the pipes of a refrigerating coil. The brine, being cooled below the freezing point, gathers its snowy covering from the moisture of the atmosphere. Above it, in the window, are pipes, curved to form the letters of the proprietor's name. They, too, constitute an expansion coil and glisten with a heavy, snowy coat. In a drug store an elaborate soda fountain exposes, not the customary pictures of frost work, but real frost. The refrigerating pipes are ingeniously carried through this fountain in such a way as to cool, without danger of freezing, the various liquids and are exposed to view in places, curved in fanciful shapes and presenting a refreshing sight of dry white frost.

In one of the largest retail dry goods houses of St. Louis, drinking water for customers and employees is furnished by a device which precludes danger of frozen water pipes and yet gives an unlimited supply of refreshment almost ice-cold, and requires no attention or replenishing. A refrigerating coil is suspended near the top of a tank filled with water. This water freezes about the coil and to the depth of several inches. Beneath this cover of ice, the water in the tank forms a bath having a temperature of 32 degrees, and in this bath lies a coil of pipe in which the city water is cooled while on its way to the drinking fountains.

As to the charges for service by the street pipe line, the intention has been to make the cost to the customer a little less than his ice bills. There is yet no meter, reliable and inexpensive, for measuring the amount of ammonia consumed, with proper allowance for the variation in density of the liquid supplied and the gas returned. The charge for service given to a customer is, therefore, proportioned to the area of the

interior surface of his cooling box, and the character of its insulation, its use, and the degree of cold required. Careful experiments have determined the merits of various materials as non-conductors of heat, and experience enables one to fairly estimate conditions peculiar to the use of a particular box, as, for instance, the frequency with which its doors are opened and its contents replenished with new and warm materials which must be chilled. Difference in rates is made for summer and for winter, and sometimes a third rate is mentioned in contracts, for the intermediate seasons.

As to the expense of a pipe line system, it is impossible to make any general statement of the cost of a central plant, as so much depends upon the variable cost of land and building in different localities and cities. The cost of laying the street mains ranges from ten to twenty thousand dollars a mile, depending upon the location of the mains, whether in alleys close to the refrigerators of most customers, or through unpaved streets, or through crowded streets where work must be done at great disadvantage and costly paving must be carefully replaced. The records of the companies in St. Louis and Denver warrant the general statement that an income of $7000 for each mile of street mains, if several miles be laid, will make the business of street line refrigeration profitable. A canvass of five miles in St. Louis showed the annual consumption, within that district, of $170,000 worth of ice, and a similar canvass of three miles in Kansas City showed a consumption of $72,000 worth of ice. It is safe to say that most American cities of 20,000 people or upward could profitably support a pipe line system, though in many cases a combination plant, such as that at Denver, where a cold storage department and ice-making business are conducted in connection with the street line circuit, would be advisable, because of the economy of the combination. The amount of business would be increased, by such arrangement, far beyond the corresponding increase in the cost of the plant and the wages and other expenses of operation.

The experiment in distribution of refrigeration by the "Fountain and Absorber" method, which has been described as proving commercially unsuccessful, was made by one of several local companies operating under patents owned by the Consolidated Refrigerating Company of New York. Its method of distribution having failed, the parent company became financially embarrassed, and its properties were eventually purchased by the International Cooling Company at New York city. This latter company also bought the patents covering all inventions made by the successful St. Louis men in their development of the street pipe line system, and secured the services of these men for the management of its own business and the extension of the system into other cities.

THE FIRST STEAM SCREW PROPELLER BOATS.

By Francis B. Stevens.

THE new steam screw propellers of Col. John Stevens, in operation on the Hudson river from 1802 to 1806, were the first to navigate the waters of any country. John Stevens was born in New York in 1749; was graduated at King's College, now Columbia, in 1768; was admitted to the bar of the colonial provinces of New York and New Jersey in 1772, and was treasurer of the State of New Jersey during the active period of the revolutionary war. In 1784 he purchased Hoboken, then an island, and residing there upward of half a century, died in 1838.

On the 26th of August, 1791, patents for improvements in the steam engine were granted to John Fitch, James Rumsey and John Stevens. The latter took out three patents; one, for a method of propelling a steamboat by the reaction of water, and another, for a multi-tubular steam boiler. In 1798 he was engaged with Chancellor Livingston, Nicholas J. Roosevelt, and Isambard Brunel, then an exiled French royalist, afterward the builder of the Thames tunnel, in making experiments on steam propulsion on the Passaic river, New Jersey. They tried a horizontal centrifugal wheel, on a boat of 30 tons, drawing water from the bottom of the boat and discharging it at the stern. This is similar to the plan that Ruthven tried in England on the Water Witch more than half a century afterward. They also, unsuccessfully, attempted to use elliptical paddle wheels.

Water wheels for mills, driven by the action of a current of water against their vanes or blades, placed obliquely to the direction of the current, have been used in China for centuries, and in Spain from the time of its conquest by the Moors. Prior to the revolution they were in use in this country for mills, and were called Chinese sculls, or tub wheels. In principle, this wheel is identical with the windmill, and, when attached to a vessel and driven by power applied to its shaft, it is the screw propeller.

Col. Stevens, in his letter to Dr. Hare, given further below, considered himself its inventor for the propulsion of vessels, but he was mistaken. It was proposed by the mathematician, Daniel Bernouli, in 1752, and is described by David Bushnell in a letter to Thomas Jefferson, dated 1787, giving an account of his submarine boat, to which this screw propeller, worked by hand, was applied, and of his attempt, with this boat, to blow up a 50-gun British ship in the harbor of New York. The same idea, of the propulsion of vessels by means of spiral wheels, was afterward suggested by Franklin, Watt, Paucton and others.

Previous to the year 1802, the screw propeller was twice distinctly patented in England, and the invention was described, in each patent, by a specification and drawing. The patent to William Lyttleton was granted in 1794. This screw propeller was a long spiral wheel, revolved by an endless rope on a pulley worked by manual labor. It was tried on a vessel at the Greenwich dock, London, and a speed of two miles an hour was said to have been attained. The second patent was granted to Edward Shorter in 1800. Shorter had two plans, one, a form of duck-foot paddles, with an alternate movement, often proposed and tried, before and since; the other, a two-bladed screw propeller, attached to an inclined shaft carried by a universal

As of special interest in connection with the article entitled "The Ferryboat of To-Day" by Col. E. A. Stevens, which appears in this number, the present contribution to the early history of screw propeller boats is reprinted from "The Stevens Indicator" by the kind permission of the author and editors.

THE ORIGINAL TWIN SCREW ENGINE AND BOILER OF COL. JOHN STEVENS. BUILT AT HOBOKEN, N. J., IN 1804.

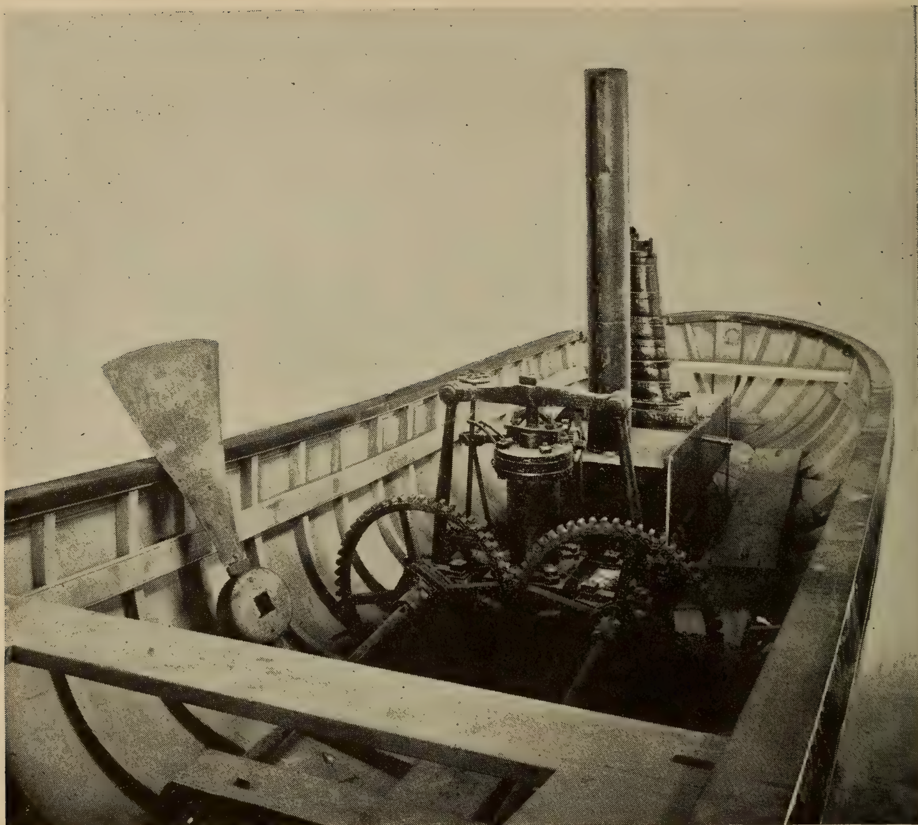
joint to the deck of the vessel. By one of Shorter's plans, but by which one is uncertain, the transport Doncaster was said to have been propelled at a speed of a mile and a half an hour by eight men working at a capstan.

The first application of steam to a screw propeller was made by John Stevens on the Hudson river in the year 1802. His experiments in screw propulsion commenced in 1801, and were continued until some time in the year 1806. The engines that he tried in 1802, 1803 and 1804 were all non-condensing, and the boilers were all multi-tubular, in which steam of a high pressure was maintained. His propeller was the short four-bladed screw propeller now in use. The following description of this boat is given by Col. Stevens in a letter to The Medical and Philosophical Journal of New York, January, 1812 :—

"To avoid the mischievous effects necessarily resulting from the alternating stroke of the engine of the ordinary construction, I turned my attention to the construction of steam engines on the rotary principle. And the first steamboat put in motion on the waters of the Hudson was one constructed on this principle. I trust, then, I shall be pardoned should I enter into a more minute description of this little curiosity than may at this time appear necessary. For simplicity, lightness and compactness, the engine far exceeded any I have yet seen. A cylinder of brass, about 8 inches in diameter and 4 inches long, was placed horizontally on the bottom of the boat, and by the alternate pressure of the steam on two sliding wings, an axis passing through its centre was made to revolve. On one end of this axis, which passed through the stern of the boat, wings, like those on the arms of a windmill, were fixed, adjusted to the most advantageous angle for operating on the water. This constituted the whole of the machinery. Working with the elasticity of the steam merely, no condenser, no air pump was necessary; and as there were no valves, no apparatus was required for opening and shutting them. This simple little steam engine was, in the summer of 1802, placed on board a flat-bottomed boat I had built for the purpose. This boat was 25 feet long and about 5 or 6 feet wide. She was occasionally kept going until the cold weather stopped us. When the engine was in the best order, her velocity was about four miles an hour. I found it, however, impracticable, on so contracted a scale, to preserve due tightness in the packing of the wings in the cylinder for any length of time. This defect determined me to resort again to the reciprocating engine."

In relation to the screw propeller of 1803, Col. Stevens, in the letter previously referred to, says :—"The unsuccessful experiment in which I had, as above stated, been engaged in conjunction with Chancellor Livingston and Mr. Roosevelt, had taught me the indispensable necessity of guarding against the injurious effects of partial pressure." (By this term he alluded to the imperfect bracing between the cylinder and shaft.) "Accordingly, I constructed an engine, although differing much from those described in the specifications of my patents, yet so modified as to embrace completely the principle stated therein. During the winter this small engine was set up in a shop I then occupied at the Manhattan Works, in Duane, near Centre street, and continued occasionally in operation until spring, when it was placed on board the above-mentioned boat, and by means of bevel cog wheels, it worked the axis and wings above mentioned and gave the boats somewhat more velocity than the rotary engine. But after having gone some time, in crossing the river with my son on board, the boiler, which was constructed of small tubes, inserted at each end into metal heads, gave way so as to be incapable of reparation."

The following account of the twin screw propeller of John Stevens of 1804, copied from an earlier American publication, is from "Stuart's Anecdotes of the Steam Engine," published in London in 1829, Vol. II., page 467 :—"At last he had recourse to



COL. STEVENS' ENGINE AND BOILER IN A BOAT RECENTLY BUILT TO REPRESENT THE ORIGINAL BOAT. VIEW LOOKING TOWARD THE BOW.

Watt's engine,* with a cylinder 4½ inches in diameter and a 9-inch stroke; the beam was omitted; the boiler 2 feet long, 15 inches wide, 12 inches high, consisted of 81 tubes each an inch in diameter; his boat was 25 feet long and 5 feet wide. This was tried in May, 1804, and had a velocity of 4 miles an hour; after having made repeated trials with her, his son undertook to cross from Hoboken to New York, when unfortunately, as the boat nearly reached the wharf, the steam pipe gave way, having been put on with soft solder. This boiler being damaged, the next one was constructed with the tubes placed vertically. The engine was kept going for a fortnight or three weeks, the boat making excursions of 2 or 3 miles up and down the river; for a short distance he could make it sail at a rate of not less than 7 or 8 miles an hour."

The following extract, in relation to this twin screw vessel, is from a paper by Dr. James Renwick, written in 1858, addressed to Frederick De Peyster, of New York, and read by the latter at a meeting of the New York Historical Society, and then published, in August of the same year, in The Historical Magazine, No. 8, of Vol. II. Dr. Renwick was Professor of Natural and Experimental Philosophy in Columbia College, New York, for many years, and was the author of several treatises on the steam engine, among which was a much-quoted article "On the Steamboats of the United States of America," contributed to Tregold's "Treatise on the Steam Engine," published in London, 1838 :—

* The reciprocating rotative engine.

"The first time that I ever heard of an attempt to use steam for propelling vessels was from a classmate of mine who resided during the summer months at Belleville, in New Jersey. He had, in the summer of 1803, seen an experiment on the Passaic river, which he stated to have been directed by John Stevens, of Hoboken. According to his account, the propulsion was attempted by forcing water by means of a pump from an aperture in the stern of the vessel.

"From some vague indications it would appear that the elder Brunel, afterward so distinguished in Europe, was in the employment of Mr. Stevens on this occasion. In the month of May, 1804, in company with the same young gentleman and another classmate, now the distinguished missionary, John H. Hill, of Athens, Greece, I went to walk in the Battery. As we entered the gate from Broadway, we saw what we, in those days, considered a crowd running toward the river. On inquiring the cause, we were informed that 'Jack Stevens* was going over to Hoboken in a queer sort of a boat.' On reaching the bulkhead by which the Battery was then bounded, we saw lying against it a vessel about the size of a Whitehall rowboat, in which was a small engine, but there was no visible means of propulsion. The vessel was speedily under way, my late much valued friend, Commodore Stevens, acting as coxswain, and I presume that the smutty-looking personage who fulfilled the duties of engineer, fireman, and crew, was his more practical brother, Robert L. Stevens.

* John Cox Stevens.

VIEW LOOKING TOWARD THE STERN

"A few years since, at the last fair of the American Institute, held at Niblo's, I was asked to serve on a committee to report upon a boat and engine exhibited by the Messrs. Stevens for the purpose of sustaining the claim of their father to the honor of being the first inventor of the propeller. The circumstances I have just recounted had taken so strong a hold on my memory that I at once recognized the engine exhibited as that which I had seen at the Battery nearly fifty years before. In respect to the propeller I could say nothing. One of my colleagues on the committee, however, Mr. Curtis, at that time United States Inspector of Steamboats for the port of New York, recognized, as distinctly as I had done, the engine, the propeller, which he had seen in the hands of the workmen by whom it was manufactured. The dates corresponded, the apparatus was avowedly made for Stevens, of Hoboken. Thus it happened that an accidental choice had placed upon the committee two persons who were, by the union of their testimony, capable of establishing the fact into the truth of which they were directed to inquire."

In relation to this twin screw propeller, Dr. Thomas P. Jones, superintendent of the United States Patent Office up to the date of its reorganization under the law of 1836, at which date commissioners were substituted for superintendents, says, in The Journal of the Franklin Institute for 1838 :—"The late Col. Stevens, of Hoboken, near New York, in the year 1805, informed the writer that he had tried such wheels in the stern of a boat, first using a single wheel in the centre. The tendency of the boat so tried was to move in a circle, a result due to the lessened resistance, as the vanes rose toward the surface, in consequence of the greater ease with which the water was removed out of the way. Subsequently, two such wheels were tried, side by side, revolving in reversed directions." This tendency of a single screw propeller to turn a vessel is also mentioned in Col. Stevens' letter to Dr. Hare, given below, and is now well recognized, a right-handed screw turning the bow of the vessel to port and a left-handed one to the starboard.

In the year 1844, by the direction of the sons of Col. Stevens, this twin screw engine and its boiler were overhauled by Mr. Isaac Dripps, then general superintendent of machinery on the Camden and Amboy railroad, and afterward in the same position on the Pennsylvania railroad. The directions to Mr. Dripps were to make no alterations or additions except in minor parts where worn. As the original boat had decayed in 1844, a new one was then built to receive the engine, and the boat with the engine then in it was exhibited at the fair held at Niblo's Garden, New York, in October, 1844, and tried on the Hudson river, where it attained a velocity of 8 miles an hour.

AMERICAN INSTITUTE,
NEW YORK, April 7, 1893.

Francis B. Stevens, Esq.

DEAR SIR—You ask me to give my recollections of the propeller boat of Col. Stevens, of Hoboken, N. J., exhibited by his sons at the exhibition of the American Institute held in Niblo's Garden in 1844; although so many years have elapsed, it is as fresh in my memory as if it occurred yesterday.

The boat was about the size of our Whitehall boats, and had a rod on each side extending to the stern, on which were attached propellers.

A supplemental report of the invention of Mr. Stevens for that year, 1844, is now in the archives of the American Institute. The report was made by General Thomas W. Harvey, the chairman of the committee of judges. Yours respectfully,

JOHN W. CHAMBERS,
Fifty-eight years with the American Institute.

Extract from "Supplementary Report of the Judges Appointed on Steam Engines, etc., Seventeenth Annual Fair of the American Institute":—

"The execution of its work shows the age of infancy in mechanical construction in this country, and on this account it is a gem; it equally shows the marks of ripe intellect and skillful adaptation to the object sought to be attained, still unsurpassed by present maturity.

"In reverting back to the time of its construction we can discover the cause why this masterly conception was laid up as useless at that time. * * *

"Respectfully submitted by your committee.

"New York, October 18, 1844.

"(Signed) THOMAS W. HARVEY,
"GEORGE N. MINES."

The twin screw engine and its boilers have been preserved in the Stevens Institute at Hoboken, N. J., and are now in exactly the same condition as when exhibited in 1844. As the boat built in 1844 has also decayed, a third boat of the same size has been lately built, and the twin screw engine has been placed in it. Different photographic illustrations of the engine, etc., its boiler, and also of this machinery placed in the boat lately constructed of the size of the original boat of 1804, are shown in the accompanying illustrations. Col. Stevens' plan for working twin screws by a single cylinder is the most simple one that could be devised. The reaction of the connecting rods against each other at their junction with the piston rod acting as a parallel motion, or as slides would do, to keep the rod in alignment. When the screw propeller came into use, after a lapse of nearly forty years, this plan of a single cylinder for twin screws was revived in this country and abroad, being known in France as the "Etoile engine." The valves on this twin screw engine are formed by two-way cocks, a modification of the single-way cocks used by Savery and Newcomen, one cock at each end of the cylinder, answering both for the admission and the exhaust of steam. The valve motion is derived from a crank on the inboard end of one of the propeller shafts. This crank works a rack, the teeth of which mesh into those of wheels on the plugs of the two-way cocks, this motion being similar to the toothed rack and segment of a wheel which Watt used, in one of his first engines, to raise his conical valves.

The boiler is one form of the multitubular boiler of Col. Stevens. It has 28 copper tubes, each 1½ inches in diameter and 18 inches long, 14 tubes projecting from each side of a rectangular chest. The grate is placed at the end of one set of tubes, and the flame passes around these tubes and then under the chest and around the tubes at the other end to the smokestack. The following letter in relation to his screw propellers was written by Col. Stevens to the well-known scientist, Dr. Robert Hare, of Philadelphia :—

"HOBOKEN, November 16, 1805.

"DEAR SIR—I have received your favor of the 8th inst. communicating an outline of Mr. Weeden's contrivance for propelling boats. The attention you have manifested on this occasion merits my warmest acknowledgments, as it evinces the interest you feel in the success of my project. But although I am persuaded I should derive no advantage from Mr. Weeden's contrivance, yet I shall ever preserve a due estimation of your kind intentions.

"With the surprising effects of the Chinese scull, I have long been acquainted.* And it is now five or six years ago that I made an attempt to apply a steam engine, the construction of which was admirably adapted to the purpose, to working a system of sculls attached to the stern of a boat, but failed of success from the inefficiency of the power in the engine I employed, owing principally to the imperfection of the boiler. But, my dear sir, I am fully satisfied, both from theory and practice, that my present mode of applying the power of a steam engine to propelling boats is in various respects preferable to any possible adaptation to the purpose of this scull with an alternate movement.

"You may recollect the description I gave you when I first had the pleasure of seeing you at Hoboken. To the extremity of an axis passing nearly in a horizontal direction through the stern of the boat is fixed a number of arms with wings like those of a windmill or smoke jack. These arms are made capable of ready adjustment, so that the most advantageous obliquity of their angle may be attained after a few trials. The principle of an oblique stroke is the same here as in the scull, but the continuity of movement in the wings gives them greatly the advantage over the alternation in the sculls, both in the loss of time and the resistance of the fluid in the change of motion ; besides

* He alludes to a mill wheel, then called the tub wheel, the Chinese scull or the flutter wheel, one form of which, developed afterward, is the turbine.

PROPELLER HUB WITH ADJUSTABLE BLADES, OF 1804.

that, this change of motion must give to the boat a wriggling movement, and it has also a tendency to elevate and depress the stern of the boat. The sculls would also be liable to be affected by the swells in rough water, and, like the paddles I had some thoughts of using, would be an awkward appendage to the stern of the boat.

"The consideration which determined me, when I saw you last, to make a trial of the paddles, was merely to avoid the necessity of giving the boat a draught of water too great for passing the overslough near Albany; but this objection to the use of wheels I expect to obviate by an increase of the number of them, and consequent diminution of their diameter. Indeed, it is absolutely necessary to have at least two, revolving in opposite directions, to prevent the tendency to rotation which a single wheel gives to the boat. Since you were here I have made a fair experiment on the wheel compared with oars. Two men were placed at two cranks, by which a wheel in the stern of the boat was turned, and with a stop watch, the time of passing over a given distance was precisely ascertained. After making a sufficient number of trials, the wheel was taken off and the same men were furnished with oars. The result of repeated trials was a few seconds in favor of the wheel. It is unnecessary to observe that the wheel must have worked to much disadvantage. The proper angle of obliquity was not attended to; besides, the wings were made with a flat surface, whereas a certain degree of curvature was necessary. And in order to give a due submer-

sion to the wheel, the axis was inclined at least 30 or 40 degrees below the horizontal line. The machinery, too, was put up in a very coarse manner.

"One very important consideration in favor of these wheels is the facility with which they can be defended from all external injury by placing them in the stern thus :—

This figure is an exact reproduction of a tracing of the pen sketch in Col. Stevens' letter.

"My foreman promises me to have the engine agoing in the boat in about two weeks from this time. I shall embrace the first opportunity of acquainting you with the result of my experiments.

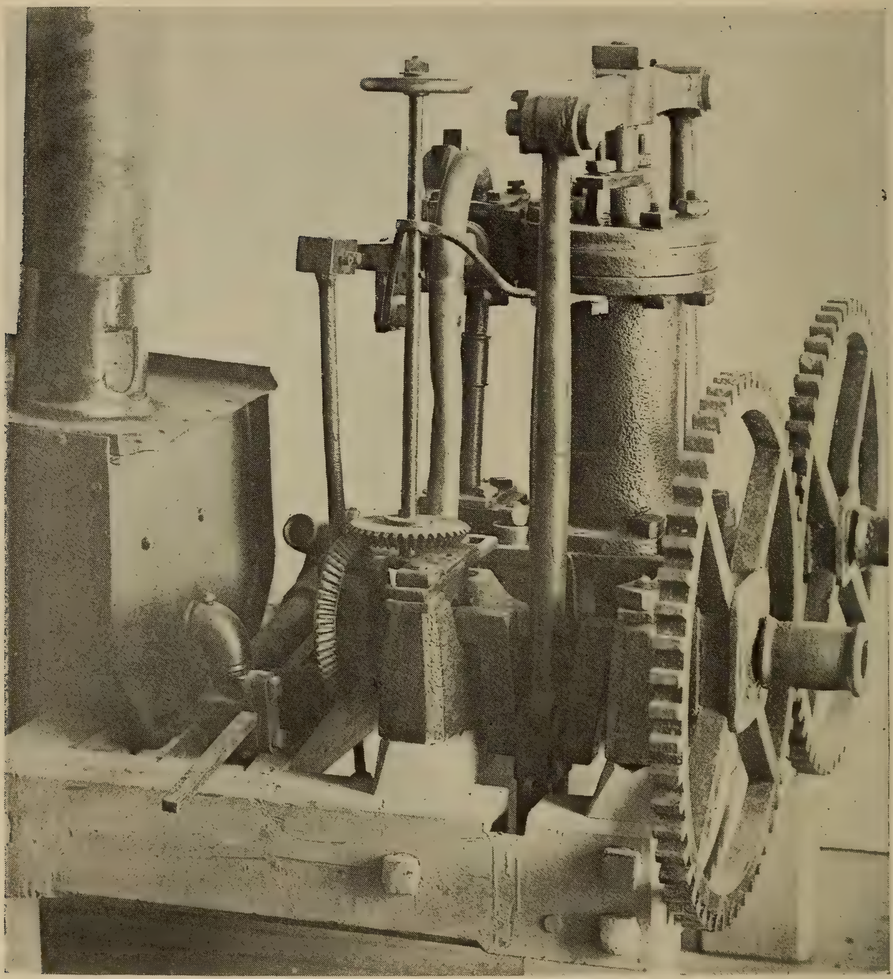
"I am, dear sir, with esteem and regard, yours, etc."

The propeller hub and blade shown on the opposite page were brought into the District Court of New York at the April term in 1844, at the request of the counsel of Ericsson and of Hogg & Delamater, in the suit of J. B. Emerson, of New Orleans, for the infringement of his patent in manufacturing the Ericsson propeller, and it was fully identified as a portion of a screw propeller used on the Hudson river by John Stevens. In this suit Emerson claimed that his patent covered the form of Ericsson's propeller, and he also broadly claimed the use of the screw propeller. The evidence of the earlier use by Stevens of the blade exhibited in court was perfect, and Emerson's broad claim was disallowed. The jury, however, awarded him damages for the infringement of the form of his screw propeller. The case was carried, on appeal, to the Circuit Court in 1847, and decided in the favor of Emerson by the Supreme Court at Washington in 1850.

This propeller blade is made in accordance with the description given in the letter to Dr. Hare. The broken shank on the hub shows this propeller to have been, when last used, the short two-bladed screw propeller of the present day, with the blades separately attached, and the two other opposite holes in the hub show that it was made to be also used as a four-bladed propeller. The blades are shown attached to the hub by a round bar or shank fitting into a corresponding hole in the hub and with its axis perpendicular to that of the propeller shaft, so that the pitch can be adjusted by slightly turning the bar or shank in the hub. In his letter to Dr. Hare, Col. Stevens says :—"These blades are made capable of ready adjustment, so that the most advantageous obliquity of their angle may be attained."

This method of adjustment is identical in principle with that of Griffiths, whose plan for carrying into effect this method of adjustment is excellent. He first proved that by making the hub globular or partially globular it could be enlarged without detriment, to a certain extent, beyond the size previously used; and, after he had discarded his automatic machinery, he utilized the hub, then only partially enlarged, for the attachment of his blades to it, by forming a flange with a plane surface at the base of each blade, and by bolting this flange to a corresponding surface made on the hub. The adjustment of the pitch is made, at the present day, by slightly altering the bolt holes of the flange. The improvement of Griffiths is regarded by the writer as the greatest made on the form of the screw propeller since 1804.

James Alexander Stevens, who was the third son of Col Stevens, and who was 16 years of age at the commencement of the year 1806, has described the propeller boat of 1805–6 as being about 50 feet long and as drawing 4 feet of water, and has stated that he was on it when it made several trial trips up the Hudson river. In this he was corroborated in a letter from his uncle-in-law, Horace Binney, of Phila-



COL. JOHN STEVENS' ORIGINAL TWIN SCREW ENGINE, BUILT IN 1804.

delphia, to whom he wrote in 1871, asking him if he remembered taking a trip on this vessel in 1805–6. Mr. Binney replied that he recollected it perfectly, mentioning that, on the return of the boat to the cove above Hoboken, some difficulty occurred in landing, on account of the draught of water of the boat. This boat is described in the letter of John Stevens to Dr. Hare as a twin screw vessel, then nearly completed. As it was a much larger vessel than the others, the defects of the machinery would have been much more manifest.

John Stevens patented his multitubular boiler in this country on the 26th of August, 1791, and the 11th of August, 1803, and in England on May 31, 1805. In addition to this boiler, two more are described in Stuart's publication previously mentioned, one having 81 tubes, each 1 inch in diameter, and the other having about 765 horizontal tubes, each 1 inch in diameter and 2 feet long, placed between two tube sheets of cast brass, each sheet being 4 x 6 feet, the tubes being spaced 2 inches from centre to centre. The tube surface was 400 square feet. Another form of his boiler, with vertical iron tubes that operated an experimen-

tal locomotive at Hoboken in 1825, is still preserved. The English patent of 1805 was taken out by John Cox Stevens, then a very young man, who described the subject of the patent, the multi-tubular boiler, as "an invention communicated to him by his father." It was he whom Dr. Renwick recognized as coxswain of the "queer sort of a boat" at the Battery in May, 1804. In after years he was the founder and first commodore of the New York Yacht Club, and commanded the yacht America in her famous race off the Isle of Wight in 1851. When in England in 1805 he went to Heathfield, the seat of Watt, who had then retired from business, and presented a letter from his father. Watt received him kindly, but reiterated his well-known objections to the use of steam at a pressure over two or three pounds above the atmosphere. These boilers of Col. Stevens have often been referred to in relation to the introduction of the multi-tubular boiler on locomotives.

At the date of the introduction into use of the screw propeller, 1838, the pressure of steam carried on the boilers of condensing engines of the vessels that now navigate the bays and rivers of the Atlantic seaboard, averaged about 30 pounds per square inch, while on the innumerable steamboats on the Mississippi and its tributaries the steam averaged 140 pounds per square inch. At the same date, the pressure on English vessels was the same that Watt had established—viz., 2½ to 3 pounds. The Great Western, in 1838, carried that pressure, and the iron screw propeller Great Britain, in 1846, carried only 5 pounds per square inch.

Col. Stevens attempted to introduce steam navigation by the screw propeller, laboring at the project for six years, and relinquishing it only one year before the successful application of the paddle wheel by Fulton. The five distinct means he proposed were :—First, the short four bladed screw propeller; second, the use of steam of high pressure; third, the multi-tubular boiler; fourth, the quick-moving engine connected directly to the propeller shaft, and fifth, twin screws. None of these means were applied to steamships for forty years thereafter, and yet all are elements in the success of ocean navigation at the present day.

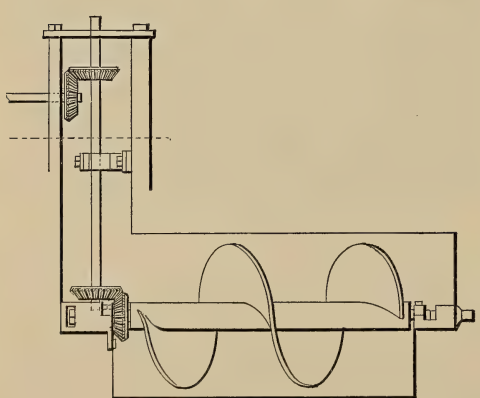
Steam engine building, as a trade, did not exist in the United States until the year 1797, although it had long been established in England. Farey in his "Treatise on the Steam Engine," London, 1827, states that in the 62 years, intervening between Newcomen's first engine in 1712, and Watt's first engine in 1774, the steam engine had been extensively introduced throughout England in the form of pumping engines for draining mines, and for raising water to turn overshot wheels, by which cotton mills and a great variety of machinery were driven ; and that as early as 1750, steam engine building had become a recognized trade in England.

The exportation from England of all machinery, was prohibited by law, except upon an order from the King in Council, until 1820, when the law was repealed. Three known instances when this order was obtained, were, for the pumping engine at Chantilly, for supplying the city of Paris with water ; for the pumping engine of the Manhattan Company, for supplying the city of New York in 1799 ; and for Fulton's rotative engine in 1806. All three engines were made by Watt. Toward the close of the last century, Hornblower, a distinguished English engineer, came to this country, and erected a pumping engine at the mouth of the shaft of a copper mine near Belleville, on the left side of the Passaic river, New Jersey, about 8 miles from New York, and established a small machine shop near by. This was then the only machine shop in the country. The second was erected in 1801 by McQueen in Duane street, New York, near the Manhattan pumping engine.

The efficiency of the tools for engine building in this country in the year 1800, can be judged by the following extracts from a letter written by P. T. Cope to the city authorities at Philadelphia, in relation to the boring of a cylinder 38½ inches diameter by 6 feet

stroke, for the pumping engine that was erected in the square at Broad and Market streets, now the site of the Municipal Building. In this letter, dated July 3, 1800, from Belleville, he says that the boring of the cylinder was commenced on the 9th of the previous April; that the boring had been in progress from that date to the date of the letter, July 3d, two men working day and night, relieving each other, "one almost living in the cylinder;" and that he expected "that about six weeks would be required to finish it."

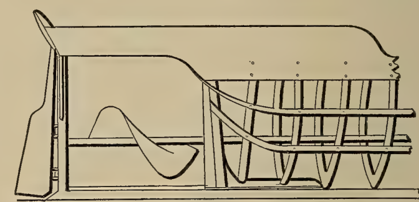
An inspection of the rude workmanship of the twin screw engine, as well as that of the boiler, will explain the reason for the abandonment by Col. Stevens, of his plan of screw propulsion. There were no tools or competent workmen in America at that date to properly construct the steam engines and the boilers that he planned between 1800 and 1806. Success was impossible. When he finally realized this, unwearied by his attempts to introduce steam navigation, dating from the year 1791, he reverted to the paddle wheel, with its slow moving engine,



SMITH'S SCREW PROPELLER. TRACED FROM HIS PATENT SPECIFICATIONS, MAY 31, 1836.

and with the boilers then in use, carrying steam at the pressure of 2 or 3 pounds above the atmosphere. He was engaged in building the Phoenix when Fulton arrived from Europe with the engine made for him by Watt in 1806, which, complete in all its details, and in these respects, far in advance of any engine that could then have been built in this country, achieved success.

Fulton's engine was the first rotative steam engine that was allowed to be exported from England. The paddle steamboat Phoenix was completed a few weeks after Fulton's vessel, and, as she was debarred from navigating the waters



CUMMEROW'S PROPELLER. TRACED FROM HIS PATENT SPECIFICATIONS, DECEMBER 10, 1828.

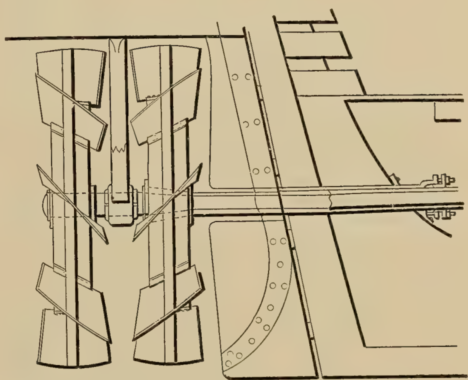
of the Hudson by the monopoly given to Fulton by the legislature of the State of New York, she was sent by sea to Philadelphia. The Phoenix was the first steamboat that navigated the ocean. Col. Stevens always maintained that with proper machinery the screw would be found superior to the paddle for sea-going vessels. In 1816, he presented a plan to our Government for a man-of-war propelled by a screw. This may still remain in the archives of the Government at Washington.

In regard to the claim in behalf of Fulton for the introduction of steam navigation, no one has admitted the justice of that claim more unqualifiedly than his unsuccessful rival. Fulton's fame, rests not merely upon the success of the Clermont in 1807, but upon what he accomplished in the interval between that date, and that of his death in 1814. Col. Stevens, in the letter to the Medical and Philosophical Society, previously quoted, says:—"It is an unquestionable fact, that he" (Fulton) "was the person who for any practical useful purpose, applied water-wheels on each side of a steamboat." And again:—"Fulton has, however, incontestably the merit of being the first person who applied steamboats to useful purposes."

The introduction of the screw propeller into use, was accomplished simultaneously by Smith in England, and by

Ericsson in the United States. Both were men of great ability. Each considered himself the inventor of the screw propeller. Each took out patents in England, in 1836, and in the United States, two or three years afterward. Each patent differed radically from the other. Neither patent, for the general application of the screw propeller, was sustained, either here or abroad, and neither Smith nor Ericsson patented additional improvements on the screw propeller. Each built small screw vessels, in England, that were successfully tried in 1837, Smith's being of six tons burthen, with a wooden screw, driven by a six horse-power engine, and Ericsson's, named the Francis B. Ogden, having about double the tonnage and power. Each built larger screw vessels that were successfully tried in England in 1839. Smith's vessel, the Archimedes, being upward of 200 tons burthen, and driven by engines designed by Rennie, of 90 horse-power, circumnavigated the island of Great Britain in May, 1840. Ericsson's vessel, the Robert F. Stockton, smaller, and with less power, was tried in England under steam, and then, in April, 1839, crossed the Atlantic under sail. Each introduced the screw propeller on merchant vessels in 1840. Each introduced the screw propeller on war vessels in 1843, Ericsson on the Princeton, and Smith on the Rattler.

Both were materially assisted in the introduction of the screw propeller into use by the improvements of those who built screw propeller vessels independently of the patents of either. The plan of Ericsson's screw propeller on the Robert F. Stockton was in exact accordance with his patent. Smith's plan on the Archimedes varied essentially from his patent. Both finally modified their screw propellers, as patented, into the short screw propellers now in common use. By the annexed drawing, traced from that of Smith's patent, his screw is shown with one long blade modeled after the screw of Archimedes, a screw for lifting water that differs radically in its action from the screw propeller. The length of the blade, measured longitudinally on the hub, is shown on his drawing to be sixteen times greater in proportion to the diameter of the screw, than that of the Rattler in 1843. This long single-bladed screw was shown placed far under the vessel's stern, while on the Rattler, in 1843, it is shown placed in the clear water, and in the position shown in the annexed drawing of Cummerow's propeller in his patent of 1828. Smith's method of connecting his screw to his engine by a vertical shaft, placed in a water-tight well, is an absurdity, equaled by his statement that his screw may be made of wood, of which material his screw was actually made, for the boat driven by a six horse-power engine in



ERICSSON'S PROPELLER. FROM HIS SPECIFICATIONS, JULY 13, 1836.

1837. Smith had great business ability, judgment and perseverance. Assisted by his friends, he organized the Ship Propeller Company, chartered by Parliament, in 1839, and, backed throughout by this company and by the English Admiralty, he introduced the screw propeller in England.

Ericsson's screw is shown in its well-known form in one of the accompanying sketches, placed in the clear water of the run, and with its two shafts one inside of the other. His patent drawing shows each of these shafts terminating in a separate crank, this not being copied in the tracing for want of space. The writer examined the machinery of the Robert F. Stockton, a few days after her arrival in the Hudson river, in

May, 1839, and, a few days after that, he examined the two propellers, one being right-handed and the other left-handed, on the wharf at Bordentown, New Jersey. Both machinery and screw corresponded with the annexed drawing of the patent taken out three years previously.

When tried on the Delaware river, the vessel was found unmanageable under steam, and the position of her rudder was changed to that shown in Cummerow's patent, and the second screw was discarded. Thus altered, with her name changed by Commodore Stockton to the New Jersey, she remained in service for thirty years. The defects of Ericsson's plan were, the unnecessary complication of the two screws, the one placed behind the other, and having its shaft running through the shaft of the other,—the small size of his rudder, and its position ahead of the screw, and in that position much too close to it ;—lastly, the form of his propeller, with its blades attached to a cylinder, which, though fairly effective, is inferior to the ordinary screw now in use.

Bourne, in his "Treatise on the Screw Propeller," published in England in 1852, says :—"Probably the exertions of either" (Smith or Ericsson) "would have sufficed to introduce the screw into practical operation." The writer ventures the opinion, that the screw propeller would have certainly been introduced into practical operation in both England and this country in the decade between 1836 and 1846, independently of the exertions of either Ericsson or Smith for the following reasons: Prior to 1836, when their patents were taken out, the subject of crossing the Atlantic by steam had been widely discussed on both sides of the ocean, and steps had been taken for regular communication across the ocean by the paddle. This was effected in 1838 by the Great Western, but the defects of the paddle for ocean navigation were then, as now, generally admitted. The accounts of the different screw propellers, that had been tried at different times, previous to 1836, had been widely published, both here and abroad, and the substitution of the screw for the paddle wheel, had been many times proposed. In the seven years previous to the patents of Ericsson and Smith, in 1836, eleven patents for the screw propeller were taken out in the United States. The plans of three of these—viz., the patent of B. M. Smith, in 1829, for twin screws ; that to Josiah Copely, in 1830, for a close approximation to the short screw propeller now in use ; and that to J. B. Emerson for a single wheel, on Ericsson's plan, in 1834, were superior to the wheels, as they were patented in 1836, of either Smith or Ericsson.

The patent records of the United States show, that up to the present time, more than two hundred patents have been taken out for various forms of screw propellers, which embody the general principle of the rotation of blades, having their surfaces placed obliquely to the axis of the shaft that turns them, this shaft being placed parallel, or nearly so, to the keel. These forms are varied in almost every conceivable manner,—many whimsical, and even grotesque,—and, yet, any one of them will propel a vessel. In the year 1840, the United States was well prepared for the introduction of the screw propeller, having then an abundance of machine shops, good tools, and excellent machinists, and the first trial of a screw propeller of almost any form, driven by a steam engine, and placed on a vessel fit for commercial purposes, must then have led to the introduction of screw propulsion.

HENRY MORTON.

By Prof. Coleman Sellers, E. D.

DR. HENRY MORTON was born in the city of New York, at the residence of his maternal grandfather, on Varick street, facing what was then St. John's Park, now occupied by the immense freight depot of the Hudson River railroad.

At the age of seventeen young Morton entered the sophomore class of the University of Pennsylvania, graduating in 1857, and on leaving college, entered the law office of Mr. Geo. M. Wharton as a student. During his last year at college and his first in Mr. Wharton's office he prepared and drew on stone the now rare volume containing translations of the hieroglyphic and other inscriptions on the famous Rosetta Stone, with numerous colored illustrations and illuminations, which received high commendation from Baron von Humboldt and other scholars. At the end of two years, however, seeing an opportunity of engaging in scientific work, which had been a favorite subject with him since his boyhood, he gave up the study of law and accepted the position of science instructor in a large endowed school—the Episcopal Academy—at Philadelphia. Here he worked and lectured for several years, until in 1864 he was offered the position of resident secretary of the Franklin Institute of Pennsylvania.

In order to augment the usefulness and pecuniary resources of this institution it was decided by the board of managers that a course of scientific lectures should be delivered in some large hall. One of the managers was even so bold as to suggest the Opera House or Academy of Music, one of the largest auditoriums then in the country, seating over 3500 persons. Others considered this too venturesome, but it was finally agreed to leave this to Mr. Morton's decision. Deputed to communicate with Mr. Morton on this subject, the present writer well remembers the characteristic courage and enthusiasm with which he at once seized on the idea of making the so far unparalleled experiment of devising and executing illustrations on a sufficient scale to render them impressive on so large a stage and to so vast an audience.

All who came in contact with him were inspired with his confidence (myself among the number), and preparations were commenced at once. Some notice of these got abroad and long before the date assigned every seat in the house was sold, and the house having been engaged for a repetition on a succeeding night, every seat for this second performance was also sold before the night of the first delivery. There are occasions, even in the life of a scientific professor, which call for no small amount of moral courage, and the evening on which, for the first time, Mr. Morton walked forward upon a public stage, in the face of an audience which crowded every seat and every foot of standing room, with the consciousness that he was committed to the absolute necessity of a success by the arrangements for the repetition was one of them. I was with him at the time, having undertaken the office of manager, to direct the work of his assistants on the stage, and I have not forgotten what were my own feelings. But when the curtain rose, he stepped forward with easy grace amid the enthusiastic applause which greeted his appearance, and began his lecture as calmly and collectedly as if he had done the same thing fifty times before. He told me afterward that he was so anxious about the success of his experiments that he had no room in his mind for personal embarrassment or the

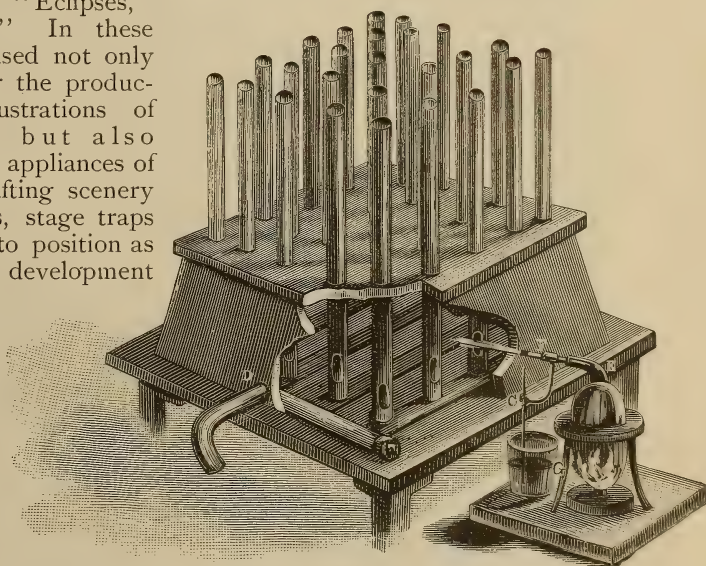
AN EXPERIMENT WITH MONOCHROMATIC LIGHT.

nervous agitation often caused by facing a great audience. I need hardly say that the lecture was a success. The clearness of the explanations and the novelty and beauty of the experiments held the audience in close attention for nearly two hours, and when Mr. Morton made his exit amid applause even heartier than that which had welcomed him, he carried with him a reputation as a scientific lecturer second to none.

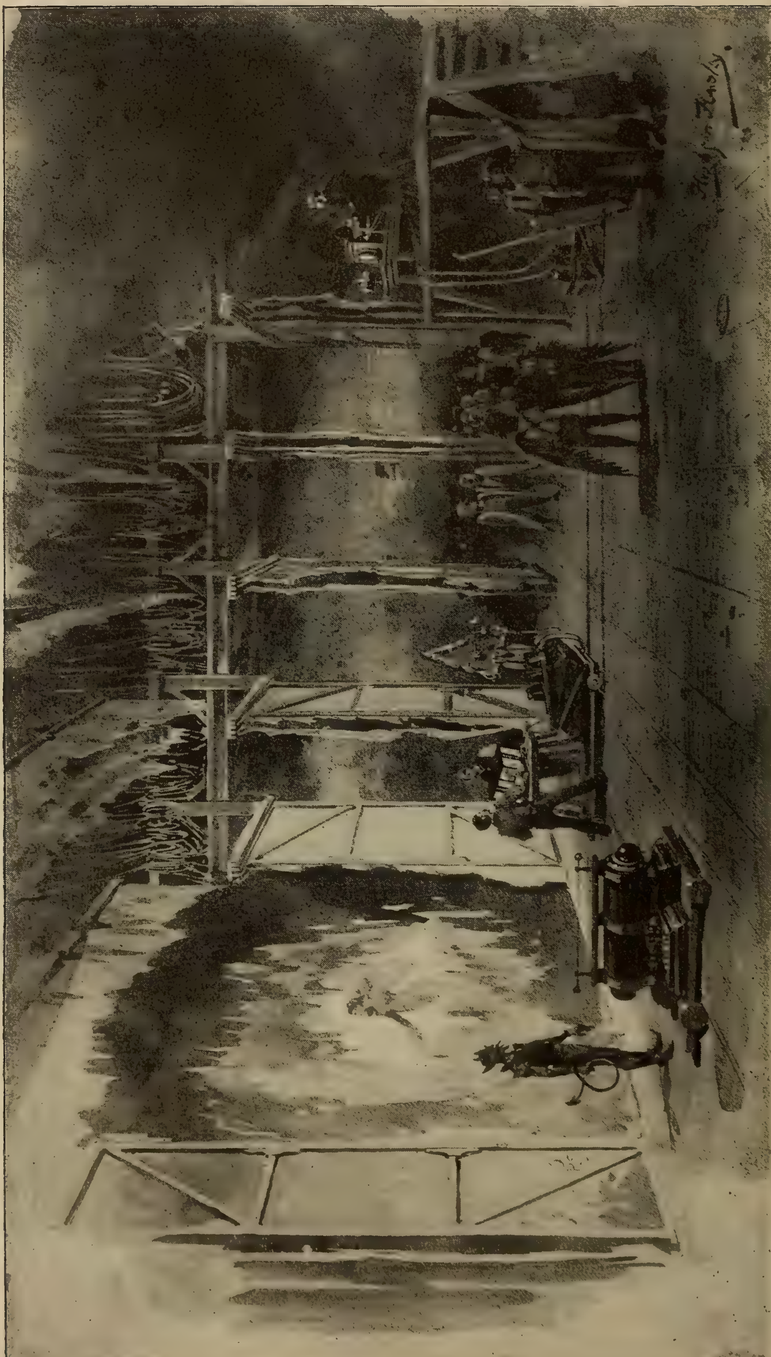
During the following years similar lectures on related subjects were given by Mr. Morton in the same place. Some of their titles were the following: "Reflection," "Refraction," "Sunlight," "Moonlight," "Eclipses," and "Fluorescence." In these lectures Mr. Morton used not only numberless devices for the production of striking illustrations of scientific phenomena, but also brought into play the appliances of the stage, such as shifting scenery to aid in color effects, stage traps to bring apparatus into position as wanted or to aid in the development of experiments. I will here describe a few of these combinations from various lectures.

It was in one case desired to show the effect of light having only one color or wave length, in the illumination of colored objects generally. When the time came for this experiment the drop curtain which had descended behind the lecturer for a few minutes was raised again revealing a brilliant "palace scene," illuminated by numerous lights judiciously placed. There then marched in a great number of masked figures in costumes representing the colors of the spectrum and bearing banners with brilliant devices. These, taking positions, formed a tableau blazing with variegated colors. Then in a moment all the lights were turned off, while at the same instant a number of monochromatic burners replaced the former illumination with floods of yellow light which lit up every part of the stage and also of the auditorium, but with the absolute extinction of every shade of color. The figures on the stage as well as the audience were in an instant reduced to grizzly phantoms, clad in gray and black. The illustration on the opposite page shows the interior of the opera house during this experiment.

Toward the middle of the stage are seen the four monochromatic burners which were devised by Mr. Morton, and which were constructed in the manner indicated by the annexed cut, in which are represented twenty-five Bunsen burners, receiving their gas supply from a gridiron of pipes and their air supply from the box which encloses their lower ends, and has but a single opening, in front of which is set a steam atomizer, by which a spray of salt solution can be, at will, driven into the box. The burners, when lit, give only a mass of blue, non-luminous flame, but as soon as the spray of salt water is fed into them with their air supply, this flame becomes brilliantly luminous, but with light truly monochromatic, or yielding only the yellow rays due to sodium.



ONE OF THE BURNERS USED IN THE EXPERIMENT SHOWN OPPOSITE.



BEHIND THE SCREEN DURING THE PHANTASMAGORIA EXPERIMENTS.

In another lecture the following effects were produced on a screen which filled the whole width of the stage in place of the drop curtain: First, the entire space of the stage seemed to be transformed into a vast tunnel, from the further end of which a locomotive rapidly advanced until it towered up of gigantic size and seemed about to plunge into the orchestra. At this moment a whistle sounded, and at once tunnel, locomotive, and all melted into an ocean grotto with a sea nymph, who presently retired into its distant depths. These phantasmagoria experiments were arranged by having a large magic lantern on an elevated structure at the extreme rear of the stage, which was 60 feet deep, and, with this, throwing large pictures, as of the tunnel, grotto, etc., so as to cover the 40-foot screen at the front of the stage. On a carriage running at right angles to the screen—that is, back and forth on the stage—were mounted two magic lanterns, with the gas bags, etc., required for their calcium lights. Each of these lanterns was provided with a mechanism by which the adjustment of the lens, securing a sharp image at various distances, caused the opening or closing of a diaphragm which controlled the amount of light passing from the lens to the screen. By this means, uniformity of illumination was secured during the change in size of the image.

Thus, in the tunnel experiment, the view of the interior of the tunnel was thrown on the screen by the large fixed lantern. Then, the lanterns on the carriage being close to the screen, a small image of a locomotive, seen from the front, was also thrown on the screen so as to occupy the far-off end of the tunnel. The carriage was then slowly rolled back on the stage, an assistant keeping the focus right by means of the rack and pinion on the lens as the image grew larger in consequence of the increasing distance of the lantern from the screen. This adjustment of the focus automatically opened the diaphragm, so that, as the image grew larger, more light passed out to illuminate it.

When the two lanterns on the carriage had reached the most distant part of their movement, the image of the locomotive was so expanded as to occupy the entire screen, and at this moment the "dissolving stopcock" was turned so as to change the light from one lantern to the other, and thus slowly change the locomotive into a nymph. At the same time that this was being done, a picture of the interior of a grotto was substituted for the tunnel in the large lantern, unnoticed by anyone in the confused effect produced by the melting of the other images, one into the other, and thus, when the sea nymph was fully defined, she was seen to be seated, not in a tunnel, but in a grotto festooned with sea weeds and strewn with shells.

On another occasion, in order to illustrate certain luminous effects of intense heat, a large pedestal was built upon one of the regular "lifts" used in connection with stage "traps" in its lowered position, so that the top of the pedestal was on a level with the stage floor. At the proper time the lecturer placed himself and apparatus on this pedestal, and was then raised to a considerable height above the stage, at which elevation he burned, in the oxyhydrogen blowpipe, a sword from point to hilt. The effect of this experiment is well shown in the illustration opposite.

These are but a few typical examples out of dozens of the same general character, which limits of space forbid my even mentioning, but I can truly say that, though I have witnessed many of the most famous scientific lectures delivered during the last twenty-five years in this country and abroad, I have never seen anything to compare with these delivered by Mr. Morton. In this connection I would relate an amusing incident of which I was a witness. When Prof. John Tyndall, F. R. S., etc., made his famous lecturing tour in the United States in 1872, he met President Morton soon after his arrival, and was hospitably entertained and offered every assistance available. Among other things, President Morton

presented him with one of his eclipse slides by means of which all the phenomena of a total solar eclipse are projected on a screen, and a large drawing in certain fluorescent substances, discovered by President Morton shortly before, and exhibiting this action in a conspicuous manner.

Now it happened that Prof. Tyndall never thought of trying this fluorescent design until, when in the midst of one of his lectures at Philadelphia, he came to speak of this property of light. Some accident of association then brought this design to his mind, and with the off-hand informality which was one of the charms of his address, he said to his assistant : "By the way, Mr. Cotterill, we have somewhere a fluorescent design which Dr. Morton gave us,— some new substance which he has discovered. If it is at hand, hold it up in the beam of violet light and let us see how it looks."

Mr. Cotterill promptly found the design and held it up, when it blazed out with intense green and blue radiance so as to startle even the lecturer, who exclaimed : "Good Heavens ! I never saw anything like that in my life." The effect of this on the audience, most of whom knew Dr. Morton personally and had attended his lecture on "Fluorescence" shortly before, may be well imagined.

In 1867 Dr. Morton was made editor of The Journal of the Franklin Institute. In 1868 he accepted the Chair of Chemistry and Physics in the University of Pennsylvania, and in 1869 he organized and conducted an expedition to make photographs of the total eclipse which occurred on August 7 of that year. This work was most successful, and its results constituted a valuable contribution to physical astronomy. In this connection Dr. Morton was fortunate enough to discover and demonstrate, by experiment, the true cause of the bright line on the solar disk along the moon's edge, seen in photographs of eclipses, which had been an unsolved problem up to that time. In the same year Dr. Morton received the title of Doctor of Philosophy from Dickerson College, Carlisle, Pa., which was again conferred by Princeton College, N. J., in the succeeding year.

In 1870 Dr. Morton accepted the position of President of Stevens Institute of Technology in Hoboken, N. J., which had just been founded by a bequest of the late Edwin A. Stevens, Esq. At the time when President Morton took charge of the institute he formulated such a working plan for the future school as the needs and knowledge of the hour suggested. This plan was purposely left flexible as to its details, and many modifications have been made, but these have always been in the line of evolution and development and not in that of abandonment and departure.

To write in any detail as to this part of President Morton's life would be to give the history of the Stevens Institute, and I will therefore in this connection only advert briefly to the generous gifts by which he has from time to time supplied what was needed to meet the growing demands of the Institute. In 1880 he presented to the trustees a new workshop which he had fitted up with steam engines and tools at a cost of over $10,000 ; in 1882 he supplied the sum of $2500 for electrical apparatus, and also contributed the salary of the Chair of Applied Electricity for a number of years ; in 1888 he presented to the trustees the sum of $10,000 toward the endowment of a Chair of Engineering Practice ; and in 1892 he presented to the trustees the further sum of $20,000 toward the further endowment of the same chair.

In 1873 President Morton was elected a member of the National Academy, and in 1878 he was appointed a member of the United States Light-house Board to fill the vacancy occasioned by the death of Professor Joseph Henry. It would be quite impossible within the limits of this article even to give the titles of President Morton's contributions to scientific literature. His researches have been chiefly on the subjects of chemistry and of light, though many other fields have been locally cultivated by him. Soon after his set-

BURNING A SWORD.

tlement at Hoboken, he was called upon to advise and assist, as a scientific expert, in an important patent litigation, and the efficiency of his investigation in this case soon led to his being called upon in others, also involving difficult scientific problems, and thus he soon gained and has since held the position of leading scientific expert in New York and its vicinity, and the revenue derived from this class of professional work has enabled him to contribute to the growing needs of the Stevens Institute of Technology, not only by the large donations already noted, but by many others involving less amounts, but large in the aggregate, and of enhanced practical value from their timely application.

One of the most prominent stenographers employed in the New York courts once said to the present writer, "We have less trouble in taking down President Morton's testimony than with

that of any other witness. He always says what he means and sees his way ahead so far that if there are ambiguities, or forms of expression likely to lead to confusion in the questions put to him by the lawyers on either side, he always straightens them out in the first instance, and so avoids the confusion which often arises from a lack of clear statement. He loses no time in making his answers and thus, without hurry, gets through a vast amount of work in a day."

The taste for drawing which led Mr. Morton in his college days to illuminate the Rosetta Stone Report continued to prove useful to him in his subsequent work. While editor of the Franklin Institute Journal he frequently drew on stone illustrations required for that publication, and constantly prepared pictures or diagrams for the illustration of his lectures.

In later life he has been able to gratify his artistic taste by collecting a number of paintings by our best American artists of the non-impressionist school, such as Hertzog, McCord, Ferguson, Bricher, Craig, Turner, Hawley, and Davis, which delight all those who take pleasure in what is intrinsically beautiful. In The Century Magazine for December, 1890, and for May, 1893, will be found examples of a poetic vein which casual acquaintances would not have suspected but which has often been a source of pleasure to his intimate friends.

THE IDEAL PREPARATORY SCHOOL FOR ENGINEERING STUDENTS.

By William Kent, M. E.

WHAT preparatory training should a student have before entering an engineering school? The preparatory training must be, of course, such as will fit the student to pass the entrance examinations of the technical school, and such as will give him sufficient mental discipline to enable him to pursue its courses. The minimum possible preliminary training would be an ordinary grammar school education plus mathematics up to that point at which the freshman class in the technical school begins. The desirable amount, however, is far greater, even to the extent of including an ordinary four-year academic or collegiate course, and, in the case of the mechanical engineering student, some workshop experience.

What should be aimed at by a preparatory school is a compromise between these two extremes. If it gives the student only such training as will fit him to enter the technical school and to pursue its studies, his education is likely to be one-sided and narrow, and when he graduates he will not have that broad foundation of general culture which the modern profession of engineering requires. If, on the contrary, it gives him the old-fashioned collegiate course, with four years of Greek and Latin, intellectual philosophy, ancient history and the like, much of his time will be wasted on mental padding which is not necessary either for mental discipline or for general culture, and is entirely useless as a professional equipment of an engineer.

With this idea of a compromise in mind, let us outline a course for a preparatory school which takes a boy at about thirteen or fourteen years of age, after he has passed through the grammar school, and prepares him to enter an engineering college in four years. In general, the course should not be narrowed by the idea that the boy is going to become an engineer, and that, there-

fore, his early training should be so shaped as to give him a bias toward engineering, rather than toward any other profession. It should rather be framed upon the idea that the boy is to become, above all, an educated man, and that at seventeen he is to be so well trained in habits of study, and so grounded in the foundations of general culture, as to be equipped to begin a technical course in law, medicine, theology, literature or engineering, or to begin a business career, according to the direction in which his desire, aptitude, circumstances or opportunities shall lead him. Few boys under the age of seventeen are qualified to choose in what business or profession they will do their life work, nor, as their tendencies and aptitudes are yet undeveloped, can their parents choose for them ; hence, the necessity that an educational course prior to the age of seventeen should be one of general culture, a foundation of all educated professions, rather than one tending toward any one profession. The old classical course is entirely too narrow to become the ideal preparatory course. It devotes too much time to the dead languages, and to mental philosophy, and too little time to natural and physical sciences, to the scientific or inductive method of reasoning, and to the training of the eye and the hand to be worthy of the name of a "liberal" education. The modern professions demand a broader preliminary culture.

Let us start with the boy leaving the grammar school at thirteen. He should then have a fair knowledge of the English language, including spelling, grammar, reading and easy compositions, and have finished the ordinary school books in geography, history, arithmetic and mensuration. The preparatory school should then give him a liberal four-years' course, as follows : English literature, rhetoric, the elements of logic, elocution and composition should be given, a little at a time, through the whole four years, including, in the last two years, some exercises in rapid composition on given subjects, during school hours, to give facility in verbal expression. As to Latin and Greek, the only instruction in these languages, in the first year of the course, should be in their relation to the English language, best studied in an "etymology," giving the Latin and Greek roots and words and their definitions, and derivation of English words from these roots. "First Lessons" in Latin with interlinear translations may be given later in the course, to give the student some idea of the structure of the language, but no attempt should be made to make him a Latin or Greek scholar. The old four, or even eight, years of Latin and Greek would be a criminal waste of time.

German and French should be given as much time as possible without detriment to the rest of the course. At the end of the course the student should be able to read both languages with only occasional aid of the dictionary. Algebra and geometry should be commenced in the first year, to be followed by trigonometry and surveying. Analytical geometry and calculus should be given in the last year to those students who are likely to enter an engineering college. For others they may be made elective. Some instruction should be given in drawing during the whole course, beginning with free-hand sketching from nature and from copy, and continuing with the use of instruments, perspective, isometric and elementary mechanical and architectural drawing, and some instruction in pen drawing, shades and shadows, and colors.

Two or three hours per week for two years out of the four may be devoted to manual training, including woodwork, modeling in clay, and if time permits, some work in metals. Lectures may be given in the elements of industrial arts, and the students encouraged to use their eyes outside of school hours in obtaining some knowledge of the arts, and to write essays and reports on what they have observed. Sufficient elementary instruction should be imparted in the natural sciences to cultivate the faculty of observation of natural objects. Short courses should be given by lectures, text books, collection of

specimens and object lessons, in botany, zoology, geology, mineralogy and lithology. Lectures on anatomy, physiology and hygiene may be included, to give the student some knowledge of the human body and of the laws of health. Elementary chemistry and physics should be studied with the aid of experiments, some of which should be made by the students themselves to increase their interest in these subjects, and give them a taste for scientific research.

As a knowledge of book-keeping is of the greatest importance to every business man, and is of great utility in many professions, it should be included in every course of liberal education. In a preparatory school for engineering students the book-keeping course should include some instruction in the method of keeping cost accounts. This may properly be given in the last year as an elective study. Instruction in penmanship may be given with the exercises in book-keeping to correct the defects of the grammar school course of penmanship. An easy course in universal history, with especial reference to the history of Greece, Rome and England, should be undertaken, together with the Constitution of the United States, and an outline of the theory of government. A few lectures may be given on the elements of political economy and social science, including the application to these subjects of the inductive or statistical method of study, in contradistinction to the *a priori* method.

In intellectual and moral philosophy only so much elementary instruction should be given as will enable students to read with understanding, as opportunity occurs later in life, the standard treatises on these subjects. Much attention given to these studies would be a waste of time, for, as Taine has said, "two thousand years of the study of metaphysics did not add a single idea to the human mind." As to the fine arts, Pycroft, in his course of "English Reading," says:—"Painting, sculpture and architecture are three subjects of which nearly all persons of polite education, professional or unprofessional, feel compelled to conceal ignorance, if they cannot display knowledge." The same might be said of poetry, music, landscape gardening and floriculture. Such instruction in the elements of these arts and in the principles of criticism as may be given in lectures or in a course of reading, might with benefit be included in the course of the preparatory school.

A sound mind in a sound body being the end of every judicious scheme of education, some systematic instruction and practice in gymnastics should be afforded to every student. Also, without reference to any religious creed, such instruction in ethics should be given as may lay the foundation for correct moral conduct, and the principles of truth, justice, temperance and philanthropy should be inculcated as necessary to the formation of the highest type of manhood.

If the criticism of the above scheme for a preparatory school be made that it prescribes a course which gives a smattering in a great number of branches of education, but a thorough training in none, the writer would reply that such precisely is his intention, as far as most of the branches named are concerned. The school is one of preparation only, and graduation from it is not the finishing of an education, but the beginning of a higher education. It aims to open to the student a view into the elements of knowledge, and to give him such a clear view into all, that, when he graduates, he will be able to determine intelligently in which direction his future course should lie, without the bias which comes both from too great devotion to any one study, and from ignorance of many others. As a preparatory school for engineers, the writer believes that the course outlined above includes not only all that is absolutely necessary before beginning the engineer's special course, such as mathematics and drawing, but much that is desirable, as manual training, book-keeping and the elements of the natural sciences, and, further, that if all the branches mentioned are neither absolutely necessary, nor eminently de-

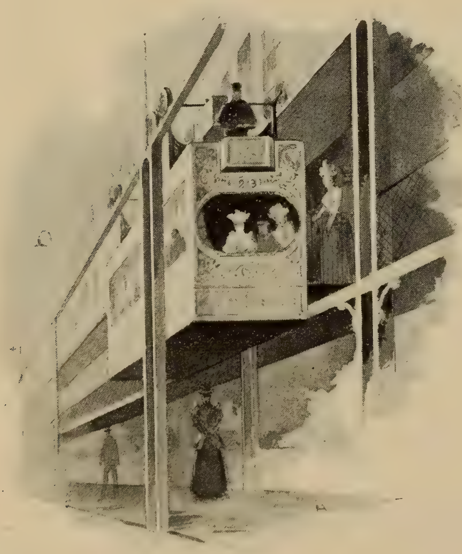
sirable for an engineer, there is none that is undesirable, and none that is not useful for culture of a broadly educated man, whether an engineer, a member of any other profession, or a business man.

Current Topics.

FOR years past schemes for signaling from balloons, raised sufficiently high above the earth's surface to be clearly seen from large tracts of surrounding country, have been repeatedly proposed, and have attracted a fair share of attention. The dangers of lights on gas balloons, however, and the bulkiness of air balloons in which gas explosion dangers would be absent, proved serious obstacles to be overcome, and it was not until the electric incandescent lamp had been successfully developed that there seemed any great promise of being able to practically accomplish much in this branch of signaling. With the incandescent lamp, of course, fire and explosion risk was reduced to a minimum, and it was fully demonstrated by experiment more than a dozen years ago that with the then comparatively new light it would be easily possible to flash messages from balloons backward and forward across country at night in a most satisfactory manner. For war purposes the value of such a system at once commended itself, and the idea was speedily worked out to a very encouraging degree, at least in England, where a London inventor for a time regularly exhibited his electric signaling balloon in operation. The balloon, as it is now remembered, was about 20 feet in diameter, and was allowed to ascend to a height of about 500 feet, being rendered visible by six incandescent lamps of 20 candle-power each, fed from a battery on the ground. The material of the balloon was translucent cambric, and when the lamps were burning, the whole glowed with a soft light, which was decidedly noticeable, and, in a clear atmosphere, could be seen for miles around. In the conductors from the battery to the balloon was inserted a Morse key by which the circuit could be made and broken, and the lamps be caused to give long and short flashes, corresponding to the dashes and dots of the telegraph code. The whole arrangement recalled, of course, the time-honored heliograph and the electric light signaling devices used aboard men-of-war, but, at the same time, it offered advantages over both. It could, clearly, be used in a flat coun-

try, or between valleys separated by low hills, instead of being confined to elevated points like the heliograph. The balloon also showed a large illuminated disk in place of the small heliograph mirror, and could be packed, together with its batteries, into little space for transport. More recently this form of balloon seems to have found favor with the Italian war department, and it is not unlikely, therefore, that more will be heard of it in the near future.

"THE Tram of a Century Hence" is depicted, substantially as shown in the annexed sketch, in a recent issue of The English Illustrated Magazine, the natural inference to be drawn from the illustration, which is made to tell its own story, being that the idea of an overhead car, running on trolley wheels,

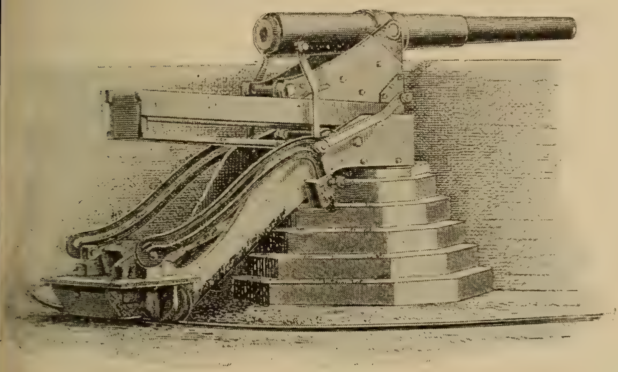


THE TRAM OF A CENTURY HENCE.

is yet a thing of the future to which we are to look wonderingly forward. After all, however, it is scarcely a startling novelty. The principle itself is many years old, and its practical application, though on a modified scale, has been made many times for the transportation of all kinds of materials, if not passengers. The well-known overhead trolley-rail arrangement to be found in any large, well-equipped machine or bridge shop for carrying heavy parts of machinery and structural work from one place to another is, in fact, a direct exemplification of it, so that, in a measure, the promised wonder of a hundred years hence is already a concrete something. Going a little further we find, moreover, that a German engineer, Eugen Langen of Cologne, has worked out plans for what he calls a suspension road, but which is nothing more than the subject of our little illustration put into working form. Mr. Langen, however, proposes to carry the two lines of rails on only one line of posts by means of brackets. The floor of the suspended car is to be about 17 feet above the street surface, and the posts, therefore, would have to be about 26 feet high. Electric motors are to be used for propulsion, the current being supplied through a contact strip carried along the girders. In the twin towns of Elberfeld-Barmen, in Germany, the building of a road of this kind has latterly been under serious consideration, so that there would seem to be some likelihood of having "the tram of a century hence" in operation long before its appointed time.

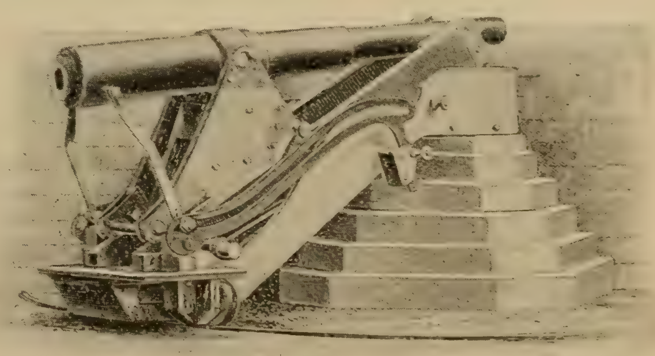
GREAT guns and heavy armor will be only incidentals in the next great war. Mechanical ingenuity in matters of offense and defense is being expended in many other lines of fully equal importance, and a vast array of war apparatus, in which even the civilian must be interested, is being put in readiness for action should the demand for it suddenly come. Not the least interesting product of military inventive genius is the disappearing gun carriage, of which no end of modifications have been proposed and, in part, executed during the past decade, though the principle of the apparatus was applied to its specific purpose much longer ago than may be generally supposed. The first arrangement of disappearing gun and carriage, mounted in a circular pit, seems to have been made on Jamestown

Island, in Virginia, in the year 1861, during the great Civil War, a conical pit having been dug in which an 8-inch gun was mounted. The piece was so placed on a platform at the bottom of the pit that, when pivoting, the muzzle was just clear of the ground. In this way an all-round fire was made possible. In 1861 and 1862 guns mounted at several other points were similarly treated, but the pits were dug deep enough to admit of embrasures. Mr. Beverly Kennon, then in the Confederate service, has been credited with the design of this early contrivance and also with that of a counterpoise battery, perfected after he had entered the Egyptian service several years later as colonel of coast defenses. This later battery, it would appear, was sunk entirely below the surface of the ground, and its guns, magazines and garrison were always out of harm's way except during the few seconds when the gun was raised above the ground level to be trained and fired. Practical test during the bombardment of Alexandria in 1882 conclusively demonstrated the value of this arrangement, and it seems strange that the capabilities of the system should not have been more widely recognized and appreciated at that time. Several years later, however, the merits of such disappearing batteries were accorded something like their just measure of consideration, and foreign powers particularly seemed to suddenly find in them advantages well worth securing, so that now they are well recognized means of defense, likely to perform important service in any international unpleasantnesses which may require the exercise of force of arms.



A MODERN DISAPPEARING GUN CARRIAGE.

It is pertinent while speaking of this American invention to recall the fact that America has three times had the honor of revolutionizing the art of war. To American armies was due the introduction of the scout, or open-order system of fighting, with all the concomitants of skirmishers, rifle-pits, etc. Foreign nations were slow to adopt it, but it came at last and is now universal. America, too, was the first to introduce the extensive use of the rifle and of sights on naval guns. To-day the rifle is the universal arm of the infantry, and a cannon without sights or means for accurate laying is as useless as one without powder. The third revolution was the introduction of the monitor, and here the honor belongs to the individual rather than to the nation.



OUT OF SIGHT.

Despite all that may have been said to the contrary, Captain Ericsson's traditional "cheese box on a raft" was an entirely unique construction; the idea had never been previously carried into practice, and certainly had never been put into successful form. The work of the monitor produced a revolution in naval ideas, of which the full extent has thus far been only inadequately realized.

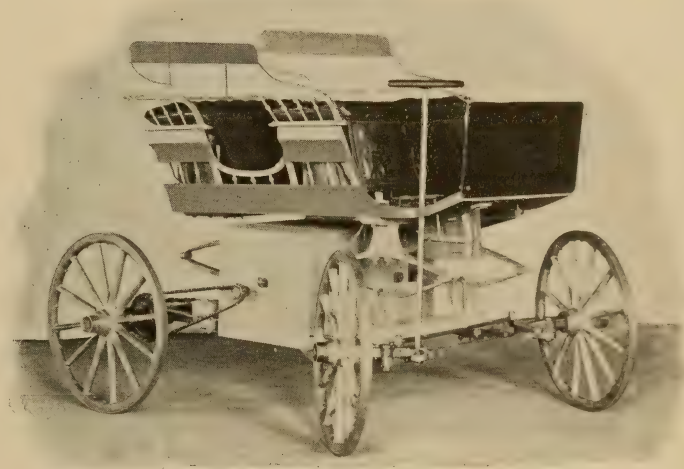
THE cost of power in the average shop, especially in the small shop, is often an unknown quantity. So long as the engine turns over and does its allotted work, all is well, and very little thought is given to the possibility of better results were time and attention devoted to their attainment. Several years ago, in a presidential address delivered before one of the prominent English engineering societies, it was stated that in an investigation instituted at about that time by the corporation of Birmingham, when considering whether they should approve of a proposal to lay down power distributing mains in their streets, it was found on indicating a number of steam engines, taken indiscriminately from among users of power, and ranging from 5 horse-power up to 30, that the consumption of coal in one instance was as high as 27½ pounds per horse-power per hour, and that in no case it fell below 9.6 pounds, the average being about 18 pounds. These figures may appear grossly exaggerated, but, as a matter of fact, they can be found duplicated in many cases. The user of a small engine is often much inclined to argue that the preventable wastes incurred in its operation are necessarily proportionately small, and hence, not worth bothering about. He may be perfectly aware of the evils of small or poorly run steam mains and exhaust pipes, leaky and imperfectly adjusted valves, and various other points affecting good economy, and yet, though his outfit be afflicted with them all, he will be quite content to let things go on as they are rather than incur the inconvenience and expense, however slight they may be, of a little overhauling. After all, perhaps, he may not be fully conscious of how much his carelessness is really costing him, and it is generally not until the matter is figured out for him and put in the form of dollars and cents that he will properly recognize the error of his ways.

Two sets of indicator diagrams, recently obtained, are quite suggestive in their way, and fully bear out the correctness of the above statement regarding the wastefulness of many small engines under prevailing conditions. One of these cards shows a heavy back-pressure, caused by using the exhaust steam for heating. The steam consumption was figured up to be a little over 200 pounds per horse-power per hour, and the coal burned was obviously far beyond what it would have been, both for heating and power combined, if the former had been done with live steam instead of exhaust. The other set of diagrams showed also a heavy back-pressure, which, however, was caused by a long, crooked and small exhaust pipe. The steam consumption in this case amounted to little less than in the other, being 192 pounds per horse-power per hour. Assuming that the boilers in these two examples evaporated about 9 pounds of water per pound of coal, we have for the coal consumption about 22½ and 21 pounds per horse-power per hour respectively. Paying for power on such bases is rather costly business.

IT is only within comparatively recent years that the idea has occurred to any one that spent molding sand, no longer fit for foundry use, has any other value than for building purposes. For these latter, in the making of mortar, its merits are, indeed, well known, the silex which forms the base of the sand having been left uninjured by the heat, while the clay and organic matter have been burnt out. In many large machine shops, in fact, whatever new buildings may be put up are done with molding sand which has first served its

purpose in the foundry. It lends itself particularly well to the colored mortars which are in vogue at the present time. If, however, as Dr. Coleman Sellers remarked recently in one of his lectures at Stevens Institute, a good quality of molding sand consists of silex with a certain clay that binds the particles of sand together, what can be more simple than the restoration of the used-up material by the addition of clays in proper proportion, or even the addition of other mineral substances that may greatly improve its quality? That this method of treatment is being thought of, Dr. Sellers pointed out, is shown in the trade by the fact that less molding sand is available for building purposes than formerly, and also that the dealers in molding sand find their largest customers using rather less of what they dig for the purpose. It is through the dealers that the methods of the managers of one foundry get to the knowledge of the managers of others, as it is quite a common thing for dealers, in seeking trade, to think that they are serving the would-be customer by informing him of what some other person may be doing in the same line, at least so far as they know. Disseminating information, in these cases at least, does not seem to have proved a profitable business practice.

THE number of storage battery carriages is growing apace. France, Germany and England all have helped in the past to swell the list of such electrically propelled vehicles, but it is only recently that American enterprise has branched out into that field too, the latest comer having been built after the designs of Mr. George K. Cummings, a Chicago electrical engineer. The vehicle is a two-seated surrey, capable of carrying four people at a maximum speed of 12 miles an hour. It is strong, capable of withstanding the more or less rough usage to which the ordinary carriage is subjected, and is comparatively free from complicated devices. A two horse-power 25-volt motor is supported on a light steel framework between the two axles. A rawhide pinion on the motor shaft drives an intermediate shaft, which, through sprocket wheels and a link belt, transmits motion to the rear or main driving axle. The front axle is rigid and carries two short supplemental movable axles to which the front wheels are attached. The direction of the vehicle is controlled through the hand wheel and shaft shown, ending in a pinion, which controls the movement of the supplemental axles. The rear wheels are both driven, but, when turning a corner or rounding a curve, an ingenious arrangement of roller clutches permits the two wheels to move independently of the shaft and of each other, so that the one on the outside of the curve automatically adjusts its speed to the distance to be gone over. The speed of the carriage is controlled by a pedal operating a switch and resistance-box, a movement of four inches of the foot

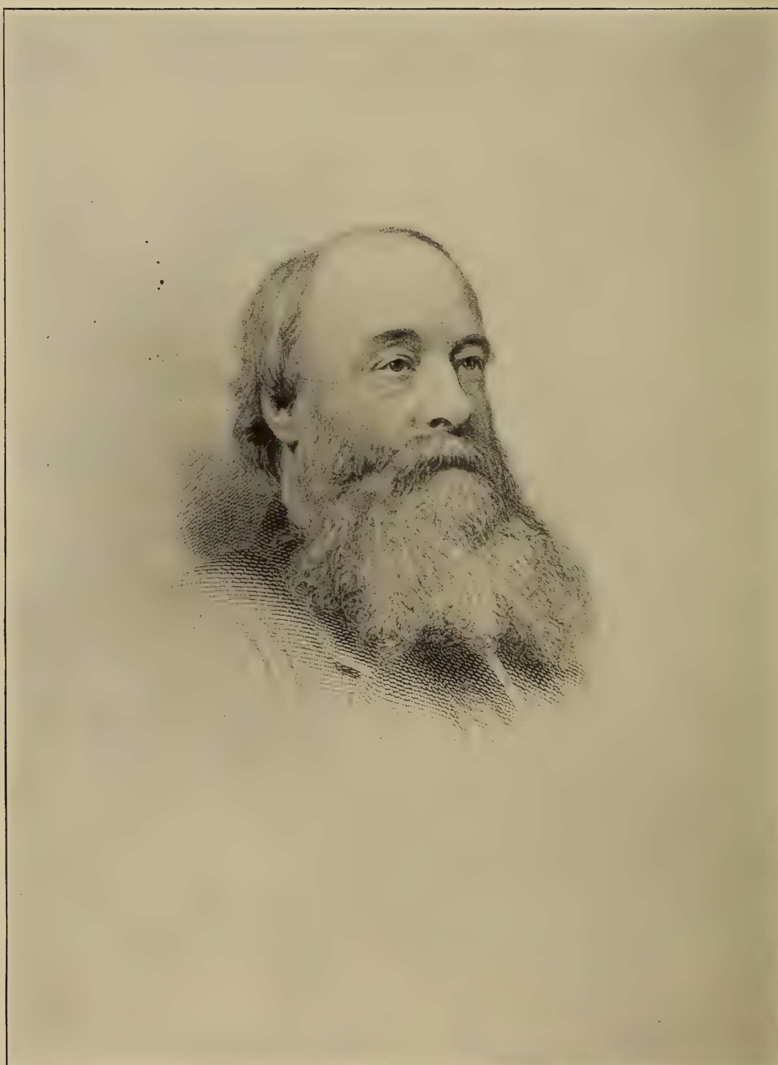


A NEW STORAGE BATTERY CARRIAGE.

changing the speed from the equivalent of a slow walk to about 12 miles an hour. Very satisfactory tests are said to have been made with the outfit, which is to be put on the market by a company to be shortly formed. Several styles of carriage are to be made, from a small one, capable of carrying only two people, to one with seating capacity for eight. Parcel delivery wagons also are to be turned out, similar in appearance to those used at present by the large dry goods shops. The question of cost of operation,—rather an important one,—Mr. Cummings claims to have answered in a most satisfactory manner with his experimental carriage, with which, on an average, a mile run was figured out to cost about four-fifths of a cent.

THERE are now in operation in the United States alone more than half a million miles of telephone line, bringing into speaking relations over 250,000 telephonic subscribers, and employing in daily service over 600,000 telephones, by means of which 600,000,000 messages are transmitted annually. These figures, given on the authority of Mr. Arthur V. Abbott of the Chicago Telephone Company, most graphically portray the remarkable proportions which Professor Bell's invention has assumed. The earliest application of the telephone necessitated a wire extending from each station to every other one with which communication was desired. How impracticable a method this is, however, for covering a territory of any magnitude can be seen without much difficulty. In both New York and Chicago, for example, about ten thousand subscribers have telephonic communication. The most compact system of underground circuits needs about 4 square inches for every 100 lines, so that, to unite each of the 10,000 subscribers with the remaining 9999, would require a space of more than a yard square simply to contain the necessary conductors. No present city street could afford the required room for the subways. If communication were thus attempted, each subscriber, according to Mr. Abbott's figures, would require nearly 200 miles of cable, and should the distribution be undertaken by means of aerial wires, pole-lines 1000 feet high would be required to accommodate the necessary circuits. It is to the impossible complexity of such a system, which became apparent even in the earliest telephonic days, that the telephone central station and the telephone switch board owe their origin and development, accomplishing to-day results whose convenience and importance are all but lost sight of in the busy whirl of existence, and can perhaps be best appreciated only by comparison with the meagre telephone facilities of a dozen years ago.

THE possibilities of natural gas evidently have not yet been exhausted. The latest use which would seem to have been found for it is the making of ice, the idea being to simply expand the gas from its usually high initial pressure down to, or near, that of the atmosphere, nature having done all the preliminary work of compression and cooling, making the gas ready to absorb heat from its surroundings immediately upon being released from confinement. All that would be necessary would be suitable coils or chambers into which the gas could be allowed to expand. It has been calculated out quite plausibly, in fact, that with an ordinary gas well, furnishing 1,500,000 cubic feet per day, something like 50 tons of ice could be turned out daily at an expense of about 50 cents a ton. The gas loses nothing but its pressure, retaining all its calorific value, and, hence, all its virtue for rolling mill and glass works use, for heating brick, lime and pottery kilns, and the endless number of other furnaces to which it is adapted. In a certain way, therefore, the gas may be regarded as affording something for nothing,—a desideratum to which many in this world are constantly looking forward.



JAMES PRESCOTT JOULE.

CASSIER'S MAGAZINE.

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MODERN LIGHT-HOUSE SERVICE.

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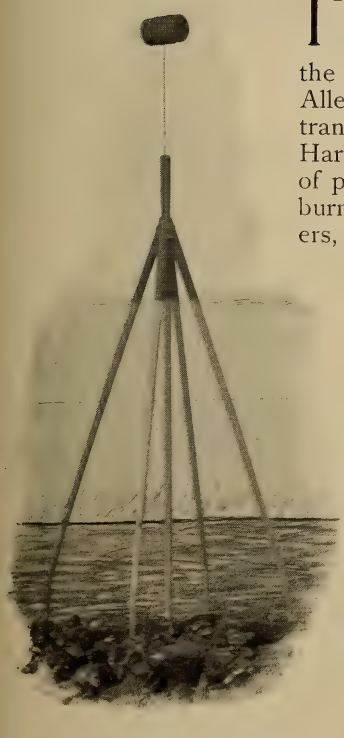
By Edward P. Adams, C. E.

Second Paper.



DOLPHIN AT HULL, MASS.

IT is a long step from the illumination of 1673 of the beacon on Point Allerton at the entrance to Boston Harbor, by "fier bales of pitch and ocum" burned in open braisers, to the perfected fountain lamps and the first order lens apparatus of to-day. Boston Light, erected in 1716, was first lighted by tallow candles; then followed the spider lamp, burning fish oil; and in 1812 came Mr. Winslow Lewis's patent magnifying and reflecting lantern. The reflectors were gradually improved and the magnifiers set aside. France leads the world in light-house illumination. The beautiful lens, clear as crystal, used in all the important light-houses, was the invention of Fresnel, and the principal manufactories of these lenses to-day are in Paris. The United States Light-House Establishment still orders its lenticular apparatus from the French houses of Babier & Fenestre, Sautter, Lamonier & Cie, and Henri Lepaute.

In 1782 the light-house of Cordouan had eighty lamps with spherical reflectors. M. Teulère, who gained distinction by increasing the height of the tower of Cordouan, in 1783 proposed parabolic reflectors and double-current-of-air lamps. The credit of these inventions has been given to Borda and to Argand. Buffon made the first advance toward making lenses in echelons, or steps, but of one piece. In 1819 Augustus Fresnel saw that, by making the lens of a number of pieces, spherical aberration could be corrected. When the United States Light-House Board took control in 1852, the reflectors were replaced by the Fresnel lenticular apparatus, found so successful in France. This system made a very considerable saving in the oil consumed, requiring about one-fourth as much as for an equally effective illumination by the use of reflectors. The lenticular apparatus consists of a central, powerful lamp around which is a cylindrical arrangement of glass which refracts the rays of

ISLE OF SHOALS LIGHT STATION, WHITE ISLAND, ME.

light from the lamp either to one horizontal plane or into parallel rays in several required directions.

M. Reynaud thus describes the dioptric lenticular apparatus invented by Fresnel :—"His lenses were composed of one central piece surrounded by concentric annular prisms, cast and ground separately and afterward solidly joined together. A section through the axis gives on one side a straight line (the lens being plano-convex, so as to render its manufacture more easy), and on the other side, circular arcs, the radii, the centres and the amplitudes of which are so calculated as to reduce spherical aberration and the thickness of the glass as much as possible. In giving the section movement of rotation around the horizontal axis passing through the focus, a lens of annular elements is generated, possessing, in common with parabolic reflectors, the property of uniting in one beam all the luminous rays emanating from the focus. Let several of these lenses be placed so as to form a prism with a polygonal base, having for its axis a vertical line passing their common focus ; place a light at that point, and turn the lenticular drum thus formed around its axis ; the luminous beams emanating from the lenses will thus be thrown in succession on all points of the horizon, and no light will be seen in the intervals between them. We shall thus have an eclipse-light (flashing) apparatus.

"If the same section of the lens be revolved around the vertical axis passing through the focus, a cylinder will be generated, and a lens of this form will distribute uniformly upon the entire horizon the luminous rays which emanate from the focus. This constitutes a fixed light apparatus.

"The figure of a third kind of lens, sometimes used, is obtained by moving the section parallel to itself in a vertical plane. This movement generates a lens, with a plane on one side and vertical prismatic elements on the other. Such a lens has the property of uniting all the rays emanating from the focus in a beam comprised between two vertical planes. It is easy to see, that by properly placing a lens of this description in

front of a cylindrical lens, it will collect the diverging rays into one beam, as is done by an annular lens."

The angle which the drum of the apparatus subtends at the focus, first fixed at 45 degrees, varies now from 56 degrees to 67 degrees. An entirely new and faultless arrangement was conceived by the illustrious inventor of the lenticular system. It consisted in transmitting the rays to the horizon by refraction and total reflection, by means of glass rings, triangular in section. In flashing lights, the lens or a part of it may revolve, or an extra vertical panel or panels may revolve around the fixed lens. If it is a shore light, a concave mirror, or totally reflecting prisms, in place of the lens on the land side, utilizes the light on that side. A lens of the first order light is 6 feet in diameter, and costs alone from $4250 to $8400; a second order lens is 4 feet 7 inches in diameter, and costs from $2760 to $5530; third order, 3 feet 3⅜ inches diameter, costs $1475 to $3650; fourth order, 19⅝ inches diameter, costs $350 to $1230; fifth order, 14½ inches diameter, costs $230 to $840; and a sixth order lens is 11¾ inches diameter, and costs $190 to $315.

"Nothing can be more beautiful than an entire apparatus for a fixed light of the first order," said the great Scotch light-house engineer, Alan Stevenson. "It consists of a central belt of refractors, forming a hollow cylinder, six feet in diameter and thirty inches high; below it are six triangular rings of glass, arranged in a cylindrical form, and above, a crown of thirteen rings of glass, forming by their union a hollow cage, composed of polished glass, ten feet high and six feet in diameter. I know of no work of art more beautifully creditable to the boldness, ardor, intelligence and zeal of the artist."

White and red are the colors of all but a very few of the lights. The lights have one of the following charac-

SEGUIN LIGHT-HOUSE, MAINE.

TABLE GIVING CANDLE POWER OF EACH OF LAMPS USED IN THE LIGHT-HOUSE SERVICE AND APPROXIMATELY ITS INTENSITY WHEN USED IN ITS APPROPRIATE LENS APPARATUS.

Illuminating Apparatus. Order.	Name of Lamp.	Candle Power of Lamp.	Candle Power of Fixed Light	Candle Power of Flashing Light.	No of Wicks.	Sizes of Wicks in Inches. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	Expenditure of Oil per Quarter. 1st Qr.	2d Qr.	3d Qr.	4th Qr.	Consumption of Oil. Per Hour.	Per Annum.
															Gills.	Gal.
1st	Funck's Float Lamp.	500	8,780	63,830	5	1"	1 13/16"	2⅝"	3 7/16"	4 5/16"	596	443	475	642	16	2,156
2d	" " "	163	4,790	33,350	3	1"	1 13/16"	2⅝"	....	....	182	135	145	195	4.80	657
3d	" " "	163	2,240	19,040	3	1'	1 13/16"	2⅝"	....	....	182	135	145	195	4.80	657
3d (old)	" " "	78	1,930	15,380	2	1"	1 13/16"	...	....	....	75	54	60	81	2	270
3½	" " "	78	1,620	11,720	2	1"	1 13/16"	....	...	....	75	54	60	81	2	270
4th	Funck-Heap Lamp...	52	598	2,842	1	1½"	....	....	....	....	59	44	47	64	1.50	214
5th	Funck's Tubular Lamp	38	298	1,200	1	1 3/16"	....	....	....	....	37	28	30	40	1	135
Lens Lantern	" " "	32	203	....	1	1 3/16"	....	....	....	....	26	20	21½	27½	0.70	95
No. 1 Range Lens	" " "	38	3,915	....	1	1 3/16"	....	....	....	....	37	28	30	40	1	135
No. 2 Range Lens	Funck-Heap Lamp...	52	6,806	....	1	1½"	....	....	....	....	55½	41½	44½	60½	1.50	202
Locomotive Headlight Lantern	" " ...	52	3,092	....	1	1½"	....	....	....	....	55½	41½	44½	60½	1.50	202
Tubular Lantern	....	..	12	....	1	⅞"	....	....	..	....	10½	8½	9½	11½	0.30	40
Light Vessel Lantern Lamp with reflector	Funck's Tubular Lamp	38	1,275	....	1	1 3/16"	....	....	....	....	37	28	30	40	1	135
Old Light-Vessel Lamp with reflector	....	18	760	....	1	1⅛'	....	....	....	....	19	13	16	20	0.50	68

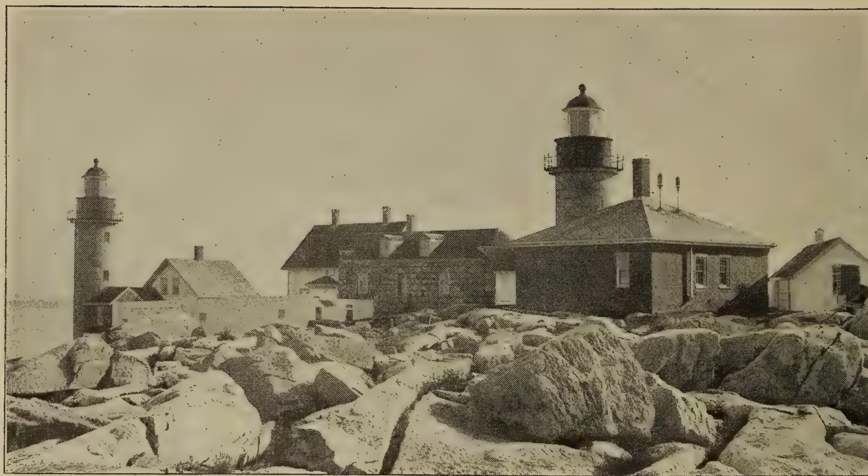
NOTE.—Candle power of 1st, 2d, 3d and 3½ order fixed and flashing lights was obtained by calculation; the candle power of all others in above table was obtained by actual measurement.

OWL'S HEAD LIGHT, MAINE, AND LIGHT-HOUSE TENDER.

teristics: 1st. Fixed white; 2d. Flashing white (from once in two minutes to once in every five seconds); 3d. Fixed white, varied by flashes; 4th. Two or three lights; 5th. Fixed red; 6th. Flashing red; 7th. Fixed red varied by a red flash; 8th. Fixed white, varied by a red flash; 9th. Flashing red and white (either alternately; or two white, one red; three white, one red, etc.); 10th. White with one or more red sectors; 11th. Green light; 12th. Occulting light. There are six orders of lens lights and five kinds of reflector lights, the latter including the old and new light-vessel lights.

A system of light-house illumination, invented by Captain F. A. Mahan of the U. S. Corps of Engineers, is to be tried this season at Minot's Ledge, outside Boston Harbor, and at Hog Island light-station, on the Virginia Coast. The plan is to designate the light-house by a number, which will be shown by flashes of light, upon the same principle as in the fire alarm system the number is indicated by sounds. The lens made by F. Babier & Cie, for Minot's Ledge, is so constructed that it will flash out the number 143 every thirty seconds, thus: one flash; dark interval of three seconds; four flashes; dark interval of three seconds; three flashes; dark interval of fifteen seconds. The revolution of the lens is very rapid, and, to reduce the friction, the entire weight of the lens is supported in mercury, as has been done recently in several French lights. The trial test of this ingenious system, to decide whether it will work satisfactorily, will be awaited with interest. The new lens at Minot's Ledge Light, flashing the number 143, has been in operation since May 1st. The flashes, though so rapid, are very bright and readily counted.

The illuminants that have been used in the United States, since the use of candles in the light-houses was discontinued, are fish oil to 1812, sperm oil to 1861, colza oil to 1867, lard oil to 1879. From 1880 to 1884, kerosene was gradually substituted for the lard oil. The highest price paid in any one year for oil was in 1875, $167,575 for lard oil; the least recently was in 1888, $10,490 for lard oil and $20,059 for mineral oil. The lowest price per gallon was 6¼ cents. The number of gallons of oil purchased in 1889 was 347,960. Gas has been tried. It is now used at three stations from city works. Compressed gas is used at ten lights, three gas buoys, and one lighted beacon. The latter is



MATINICUS ROCK LIGHT, MAINE.

in New York Harbor on Dry Romer Shoal. An iron pier, 30 feet in diameter and 16 feet high, is surmounted by a skeleton iron tower 25 feet high. The fixed white light of the fifth order is supplied with gas from a tank which holds ninety days' supply, so that no keeper is needed. The pier, tower and apparatus cost less than $15,000. Two gas buoys are in Boston Harbor. Each holds ninety days' supply. A combination gas machine is used to furnish the light to some of the stations on the Northwestern lakes. It has worked so well that it will probably come into more general use.

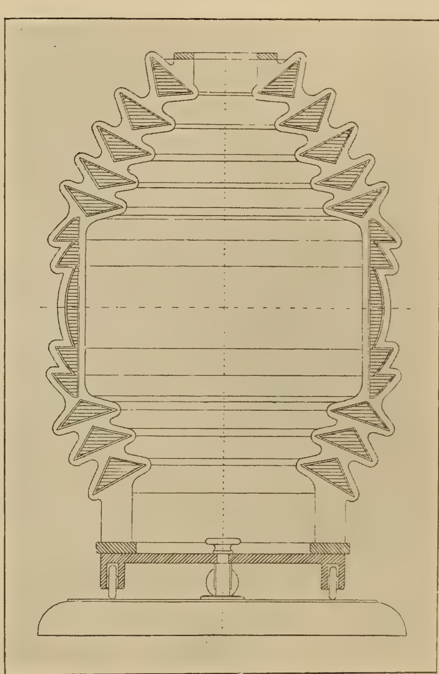
Experiments have been made with the electric lights. The tallest skeleton iron tower erected by the United States Light-House Service was at Hell Gate, at New York, in 1884. Its height was 255 feet. It cost $11,000 and had nine electric lights of 6000 candle power each. At night, when lighted, the effect was grand, but the light dazzled the pilots and prevented them from seeing objects beyond the circle illuminated, and the shadows thrown looked like obstacles. The light was, therefore, discontinued. The statue of "Liberty Enlightening the World" is under the care of the Light-House Board and was, until very recently, lighted by electricity. The nine duplex lights in the torch, at a height of 305 feet, were visible 24½ miles at sea. Five single lights, shielded from the water side, in the fort at the base of the statue, illuminated the statue itself. In addition, after October 21, 1892, there was a vertical beam of red and yellow light seen only by reflection from the haze or dust in the air. The face and bust of the statue were illuminated by a powerful search light from one of the salients of the fort, and the coronet was decorated with red, white and blue incandescent electric lights. The nine lamps in the torch were replaced by one of 5000 candle power, showing through a glazed belt of plate glass eighteen inches high. As a measure of economy its lighting has been discontinued.

A series of six lighted buoys at Gedneys channel entrance to New York Harbor are lighted by electric lights of 100 candle power. Cables run to the power house. Sandy Hook east beacon is lighted by electricity. Electricity is likely to be used at nearly all the primary sea coast stations at no distant day.

Fire Island light will soon receive a new equipment for its illumination with electric lights. Fire Island is the long, low strip of land that cuts off the Great South Bay, on the southerly Long Island shore, from the Atlantic Ocean ;

and Fire Island light on the western side of the island, forty miles east of New York Bay, has been for many years one of the best known and most important lights on the Atlantic Coast. All the transatlantic steamers bear for the light, not only to verify their positions, but to insure being seen and reported by the operator in the ship-news tower. The light-house rises 168 feet above the sea. At present, a flash is made every minute by the revolution of the eight-panel lens. The new light will have a bi-valve lens, nine feet in diameter, known as a "lightning light," made by Henri Lapaute & Sons, of Paris, and costing nearly $10,000. The depth is only six feet. Through the lens runs a spindle, which is set in a pivot above and below, but nearly the entire weight is supported in mercury. Attached to the lower end of the spindle is a drum-shaped float, which is made slightly smaller than the open cylinder in which it is to rest, and that is about two feet in diameter. The cylinder contains mercury, which entirely surrounds the float, and as the weight is almost altogether on the mobile liquid, the friction is hardly appreciable.

"No appropriation made by Congress accomplishes as much, so promptly, and with such satisfaction to its immediate beneficiaries, as that for lighting rivers. About 1705 lights are now maintained, at a cost of about $166 per year for each. They have revolutionized steamboat navigation, making it almost as easy and as safe to run by night as by day, while before the system of lighting rivers was established, it was usual for steamers to stop running and tie up to the banks during the dark nights. Not only is time now saved to steamboats by these lights, but there is a direct saving of money to both owner and shippers in shortening the time in which trips are made, in reducing rates of freight and insurance, and in reducing liability of the boats to disaster. The tonnage on the great Western rivers on June 30, 1892, was 310,802.68, according to the Bureau of Navigation." This is quoted from the annual report of the Light-House Board for 1892, and clearly indicates how important are the post lights on Western rivers. "They meet a popular want quickly and well, and serve their purpose admirably." The river light is put in a class by itself, as its life is temporary, and its location a shifting one. Though found in most of the light-house districts, it is maintained from a separate fund and is governed by different regulations. Seven hundred and eighty of the lights are on the Mississippi river, and 458 are on the



SECTION OF A SIXTH ORDER LENS.

Ohio river. St. John's river, Florida, comes third with 81 lights. There are not over 45 on any other river. The sum of $300,000 was appropriated for lighting rivers in 1894.

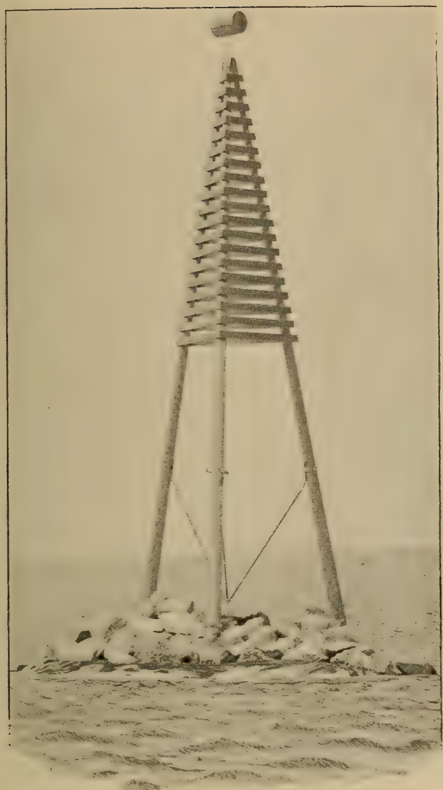
In the words of Mr. Johnson, "the purpose of a light-ship is to do the work of a light-house in a place where one is necessary, but where it has not been erected because of the great difficulty, not to say expense, of such a structure. But the light-ship should have the permanency and efficiency of a light-house, and should give as good a light in clear

weather, and sound as far-reaching a fog signal in thick weather. To insure permanency of position is a matter of great difficulty. When moorings have been made too heavy to drag, chains have broken; when they have held, mooring-bitts have been torn out; when these have held, the ship has floundered at her anchors, or the cable has been slipped, and the ship has sought a harbor or gone to sea for safety. But under the present rules of the Light-House Board, rigid inspection is frequently made of the riding-gear of the light-ships, and the absence of a light-ship from her moorings is now quite unusual."

Of the thirty-three light-vessels in the United States on June 30, 1893, twenty-eight are on the Atlantic coast, four on the Lake coast and only one on the coast of the Pacific Ocean. The latest built vessels, which are the largest and strongest, are anchored in the open ocean; the older and smaller vessels are moored in the sounds and bays. Three of the most recently constructed light-vessels have steel frames, are sheathed with wood and have all the modern improvements, including twelve-inch steam fog-whistles. They are the most powerful and complete light-vessels ever built, and cost about $60,000 each. One of these light-ships is located at Great Round Shoal, in the open ocean off Nantucket; another at Bush's Bluff Shoal, Hampton Roads, Va.; and the third in the Pacific Ocean, off the bar of the Columbia River. Each light-vessel is a strongly built schooner, showing at each mast head an iron frame-work ball, to distinguish it from an ordinary vessel during the day, and at night one or two lights are hoisted on supplementary masts just back of the vessel's masts and attached to them at the top. Each light is composed of eight 12-inch reflector lamps hung in gimbals and surrounding the supplementary mast. All the light-house vessels have some kind of a fog-signal and several have steam whistles of great size and power.

POLLOCK RIP LIGHT-SHIP, NANTUCKET SOUND, MASS.

Pollock Rip Light-ship, illustrated on this page, was built in 1887, and is about 120 feet long, with nearly 27 feet beam and 12 feet 5 inches depth of hold. To keep her from dragging her anchors this vessel is now fitted with moorings as heavy as for a frigate. In spite of brilliant lights and powerful 12-inch steam fog-whistle, she has been repeatedly run into by passing vessels. The cost of this vessel was $50,000, and it costs about $8000 per year to maintain and keep it in repair. On account of



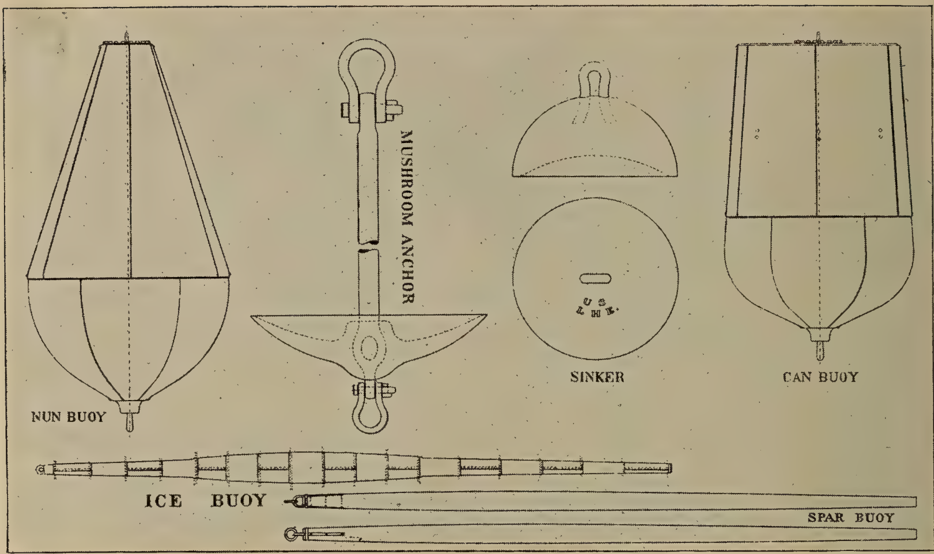
TRIPOD AT CHANNEL ROCK, ME.

this expensive maintenance, as well as the difficulty of keeping them in position, it is the policy of the Light-House Board to replace light-ships with light-houses as fast as possible. Cornfield Point light-ship, built in 1892, of about the same length as the Pollock Rip light-ship, has a depth of hold of 14 feet 6 inches. The hull is iron; the boilers are steel. The vessel is fitted with steam windlass and distilling apparatus, and a 12-inch steam fog-whistle. There are four lens-lanterns on each mast, 55 feet above the water, fitted with electric lights, eight incandescent lamps of 100 candle power each. A flashing contrivance, devised by Maj. Heap, is arranged in the electric circuit. The electric installation cost about $4200, and the first year's maintenance was about $12,800.

Some of the English light-ships show revolving lights. The Shamble light-vessel has a long flash of five seconds, followed by a short flash of one and a half seconds, each of 1000 candle power. Similar illumination of light-vessels will soon be used in the United States. A revolving light has recently been fitted to the foremast of the Sandy Hook light-vessel, and another to the foremast of Relief light-vessel No. 16. A small steam engine actuates the vertical shaft. The former has been in use over two years and is considered by mariners a great improvement over the previous fixed red lights on both masts.

To aid in the construction and maintenance of the aids to navigation, the Light-House Board of the United States have thirty steamers and two sailing tenders. Those under the charge of the light-house engineers are used for freighting building material to light-house sites for construction and repairs and for conveying working parties from station to station. The Madroña is typical of the best of those built of wood. She is a screw steamer, schooner rigged, 152 feet long, with a derrick attached to the foremast, operated by a hoisting engine. This tender fully

A LIGHT-HOUSE STEAM TENDER.



SOME BUOYS AND ANCHORS.

equipped cost $60,000. Those steamers in charge of the light-house inspectors are used in attending to the buoyage of the coast, exchanging every buoy for a fresh one once a year, and setting new buoys. On these the inspectors visit the light-stations to make their quarterly inspections and pay the keepers, and they are used also to carry provisions, fuel and minor supplies to the light-stations. The new tenders, Azalia for the New England Coast and Marigold for the Great Lakes, are steel screw steamers 150 feet long, with triple expansion engines and two cylindrical tubular boilers, to carry 150 pounds of steam. Each has eight water-tight compartments, and cost about $80,000. The latest twin-screw steam light-house tenders are the Lilac on the coast of Maine, the Columbine on the Pacific Coast, the Amaranth in Lake Huron, and the Maple on the coast of Maryland. The steel steamer Armeria, 201 feet long, with twin screws and two high pressure boilers of 1250 indicated horse-power, has taken the place of the Fern as a supply steamer for the Atlantic and Gulf coasts.

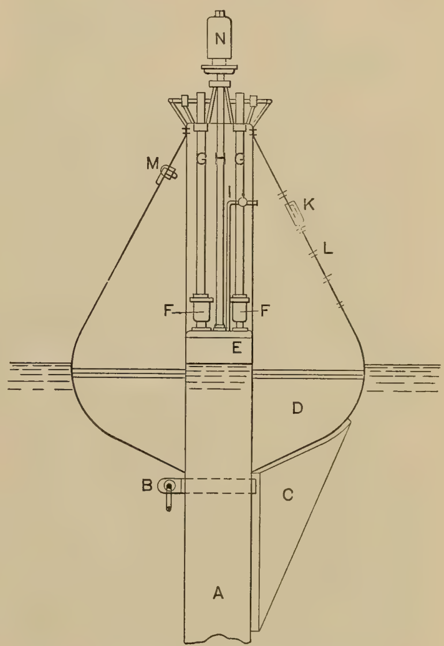
The term "beacons" includes all the aids to navigation built upon the ground or ledges and includes light-house towers which serve as beacons by day. Stone beacons and iron spindles, usually surmounted by an iron cage or ball, wooden cask or wheel with wooden pendants; wooden tripods, sometimes surmounted by a special day mark; and wooden dolphins made of five piles, are all included under this class of day-marks. Buoys are floating aids or day-marks. The various kinds are better shown by illustration than by description. They are nun buoys, first, second or third class; can buoys, first, second or third class; cone buoys; spar buoys of wood or of iron; ice buoys; bell buoys and whistling buoys. They are all anchored by chains or wire ropes to sinkers or to anchors, and show by their color and number their positions on the charts.

In conformity to the revised statutes of the United States the following order is observed in coloring and numbering the buoys along the coasts or bays, harbors, sounds or channels:—In approaching the channel from seaward, red buoys, with even numbers, will be found on the starboard side of the channel; black buoys, with odd numbers, will be found on the port side of

the channel; buoys painted with red and black horizontal stripes will be found on obstructions, with channel-ways on either side of them; buoys painted with white and black perpendicular stripes will be found in mid-channel, and must be passed close to avoid danger. Perches, with balls, cages, etc., will, when placed on buoys, be at turning points, the color and number indicating on what side they should be passed. Different channels in the same bay, sound, river or harbor, will be marked as far as practicable, by different descriptions of buoys. Principal channels wlll be marked by nun buoys; secondary channels by can buoys; and minor channels by spar buoys. When there is but one channel, nun buoys, properly colored and numbered, are usually placed on the starboard side, and can buoys on the port side of it. Day-beacons, stakes, and spindles (except such as are on the sides of channels, which will be colored like buoys), are constructed and distinguished with special reference to each locality, and particularly in regard to the background upon which they are projected.

During fogs and at dangerous places distant from lights, sound-signals are necessary to guide mariners in a safe course. Guns or cannons, rockets and gongs, have been used for these signals, but have not proven very satisfactory. The fog-signals now in use are steam sirens, steam whistles, condensed air trumpets, whistling buoys, bell buoys, bells struck by machinery, and bells rung by hand in answer to signals. The whistling buoy and bell buoy, being automatically sounded by the motion of the waves, are useful to mark dangerous places away from light stations, at all times. Bells are in use at most of the light stations. Those run by machinery are actuated by clock-work made by Mr. Stevens of Boston, and are arranged to indicate their location by the time interval between the single or double strokes of the bell. Recent experiments have shown that with a much heavier hammer and stronger blow, the bells can be heard much farther, and that the booming of the bell can be heard farther than the initial stroke.

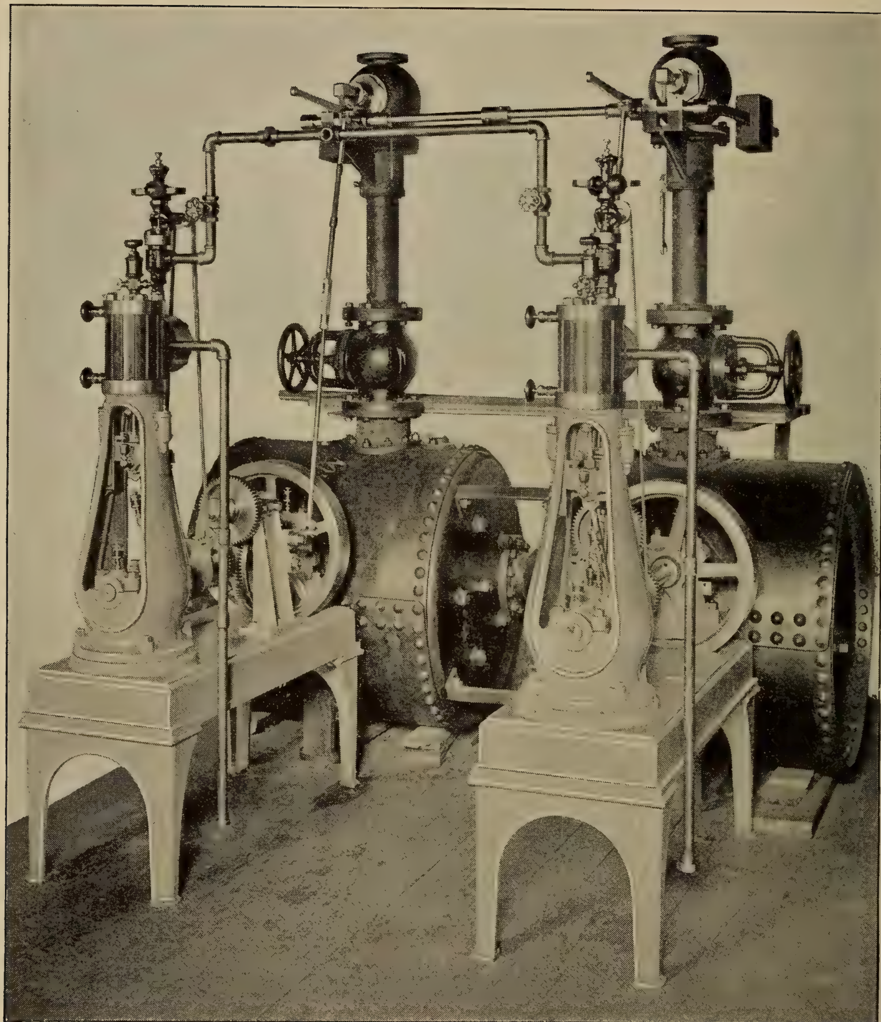
Brown's bell buoy, invented by an officer of the Light-House Establishment, consists of a decked and weighted iron buoy 6 feet 6 inches across the deck, with a frame-work of 3-inch angle-iron, 9 feet high. The 300-pound bell is rigidly attached to the top with a radial grooved iron plate just below it. A cannon ball rolling on the plate tolls the bell when there is any wave motion.



COURTENAY'S WHISTLING BUOY.

They cost, without fittings, mooring-chains and sinkers, about $300 each. There is also in use a modified form of this bell buoy, in which the bell is struck by four steel balls rolling in as many horizontal tubes outside the bell.

The whistling buoy was patented by J. M. Courtenay of New York. It consists of an iron, pear-shaped buoy 12 feet wide, for the largest size, and floating 12 feet out of water, with an inside tube, 33 inches across, extending through the bottom of the buoy to a depth of 32 feet into water free from wave motion. The tube is open at the



STEAM FOG-SIGNAL MACHINERY.

lower end, but at the top is closed with the exception of three holes, two being air inlets and the middle one the outlet by a 2½-inch pipe to the 10-inch locomotive whistle which surmounts the buoy. As the buoy rises, the water sinks relatively in the tube, and as the buoy sinks the water rises forcing the air through the whistle. This is the largest of the four sizes and weighs 12,000 pounds. The smallest whistling buoy is six feet in diameter and weighs but 2000 pounds. The accompanying diagram of a Courtenay buoy more specifically explains its arrangement. The cylindrical tube A projects below the level of the water. On the upper part of the tube there are a whistle N and also two inlet valves FF so that the rise and fall of the buoy draws in and expels the air alternately. It is said that an undulation of even 12 inches is sufficient to sound the whistle. The buoy is fitted up with a mooring shackle, B; a rudder, C; inlet tubes, G; a manhole, K; reached by the steps, L; and a lifting ring, M. These buoys cost about $1100 each, and their mournful

sound can, at times, be heard 15 miles. But there are aberrations in the sound of all fog signals, that are hard to explain, and that cause them to be inaudible at places scarcely a mile distant.

The locomotive whistle on account of its sharpness or shrillness makes a good fog-signal. Its use for this purpose was first suggested about 50 years ago by Mr. A. Gordon, C. E. The whistle was first practically used as a fog-signal at Beaver Tail Point, Narragansett Bay, erected by Mr. Daboll under the direction of Professor Henry, then chairman of the Light-House Board. The steam at high pressure passing through a circular slit against the edge of the thin bell of the whistle causes a strong and rapid vibration. Difference in pitch in the sound produced is made by changing the distance between the steam orifice and the edge of the bell. The sound is diffused equally on all sides but is strongest in the plane of the edge of the bell. The diameter of the bell is from 6 inches to 18 inches, 10 inches being the most common for fog-signals.

The Daboll trumpet was invented by C. L. Daboll of Connecticut. The largest trumpet is 17 feet long, measures 3½ inches in diameter at its throat and 38 inches across its mouth. Connected with this is a resounding cavity and a steel tongue or reed, 10 inches long, 2¾ inches wide, and 1 inch thick at its fixed end. Air is compressed in a reservoir and driven through the trumpet by an Ericsson hot-air engine at a pressure of from 15 to 20 pounds. The trumpet does not require as much power as the steam whistle, but it more frequently requires repairs, and more skillful management is necessary to prevent deterioration in the sound. It is best suited to a station where water cannot be readily procured. The engine and trumpet cost $3600. Since Delamater & Co., who manufactured these engines, have gone out of business, a similar fog-signal with a Rider hot-air engine was installed by Maj. Heap at Penfield Reef light-station, on Long Island Sound. The engine burns only 10 pounds of coal per hour for about 5 pounds of pressure required. The total cost of this apparatus is about $2000.

The siren, invented by Cagniad de la Tour, was adapted to use as a fog-signal by A. and F. Brown, of New York, under the direction of Professor Henry. A first-class fog-siren has a trumpet like the Daboll trumpet. The sound is made by driving steam through radial slits in a fixed and a rapidly revolving disk placed in the throat of the trumpet. There are 12 radial slits in each disk, and the moving disk revolves 2400 times in a minute, thus producing 480 vibrations per second. A pressure of 50 pounds of steam is required; and under the most favorable circumstances the first-class siren can be heard at a distance of from 20 to 30 miles. It is made in various sizes. A "self-acting siren," made by the same firm, is not so expensive and nearly as effective. It requires no engine, as the steam itself revolves the disks. A "Crosby signal," a clockwork device, gives the characteristic automatically, and automatically winds up each time the siren blows. One of them, in duplicate, is at Execution Rocks light-station on Long Island Sound, and cost $925 without boilers. A first-class siren, in duplicate, without boilers, cost $4800. The Light-House Board has bought the patent on the Crosby signal. Experiments have been made with a smaller siren, costing about $500, and consisting of a hot-air engine and a centrifugal blower.

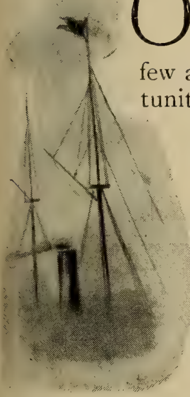
From the results of experiments made by General Duane, the power of the first-class siren, the 12-inch steam-whistle and the first-class Daboll trumpet were expressed thus: Siren, 9; whistle, 7; trumpet, 4; but the relative expenditure of fuel, siren, 9; whistle, 3; trumpet, 1; and the relative economy of fuel, siren, 1; whistle, 2⅓; and trumpet 4. Length of blast and varying intervals between blasts in these three kinds of fog-signals indicate to the mariner the location of the fog-signal he hears. The ninety steam and hot air fog-signals of the United States have cost about $7500 each, and the yearly

expense of maintaining them is about $1250 each.

As has been said, the sound of fog-signals are subject to aberrations not easy to explain, so that they may be heard loudly where we would expect them to be heard faintly, and heard faintly, or not at all, where we would expect them to be heard loudly. It seems proved that the mariner approaching a fog-signal from the windward, should go aloft, and when approaching from the leeward, he should go as near the surface of the water as possible, to pick up the sound of a fog-signal most quickly. The mariner should not judge his distance from a fog-signal by the intensity of the sound, nor by failing to hear it. He should not expect to hear a fog-signal as well when the upper and lower currents of air run in opposite directions, nor when there is a swiftly flowing current of water, especially when the tide and wind run in opposite directions, nor when there is an electrical disturbance, nor when the sound must reach him overland. A bluff behind a fog-signal appears to cause irregular intervals. From one to four miles to the windward of a fog signal there is often a "dead space" where the signal cannot be heard. The cause of this aberration and the remedy for it, which can be found only by careful research and experiment, are now undergoing investigation.

THE AUXILIARY MACHINERY OF AN OCEAN GREYHOUND.

By Henry L. Ebsen.

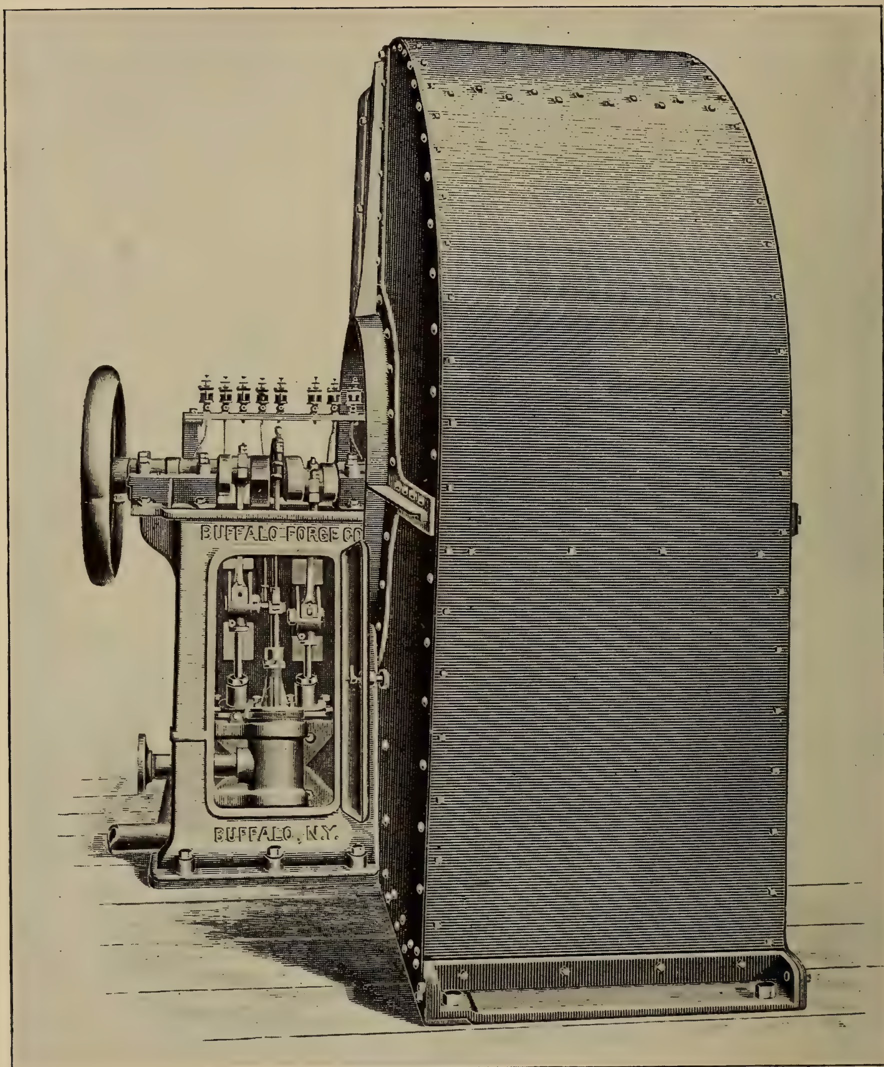


OF the throngs that annually surge back and forth across the Atlantic, comparatively few avail themselves of the opportunity of descending into what seem grimy depths of their temporary floating homes,—the engineer's realm, where throbbing engines, fiery furnaces and monstrous boilers unite their energies in speeding the great ship onward. They know that somewhere, down below there is a maze of wonderful machinery and a small army of faithful toilers, by no means resplendent in blue cloth and brass buttons, but upon whose efforts much of their safety and comfort depends ; even the venturesome ones, however, that dare penetrate into this sphere of mysterious agencies, carry away with them only an inadequate idea of all that it contains. True, they have seen, in part at least, the mighty engines, towering above them, ceaselessly turning ponderous shafts ; they have, mayhap, even braved the stifling atmosphere of the stokehole, where greedy mouths of endless rows of furnaces hungrily yawn for coal, fed in by half-clad men, seeming imps of darkness, with ever busy shovel.

This is but part, however, of what the bowels of the great ship harbor. Of what is known as the auxiliary plant of the vessel, the visitor sees little, and impressive though his trip to the lower regions may have been, his conception of the actual machinery equipment remains vague indeed. There are electric light engines and dynamos, steering gear machinery, refrigerating apparatus, hoisting engines and ventilating outfits, and pumps in endless array, mere mention of which would be a revelation to him, and whose importance, withal, is of the first order.

Roughly speaking, these auxiliary appliances require for their operation about one-tenth of the steam supply furnished to the ship's main engines, representing the equivalent of from two to three thousand horse-power on steamers of the larger sizes. When a vessel is in port this steam is supplied by one or two boilers,—donkey boilers as they are called,—smaller than the main boilers, and usually located on the main deck, or some other deck above the water line, so that in case of an accident, which would submerge the main boilers, there would still be power available for pumping and lighting purposes. These boilers have their own feed pump, and their stack runs up inside of one of the main stacks. The auxiliaries, which are indispensable to the working of the engines and boilers, but which work entirely independent of the main engines, are the feed pumps and the circulating pumps. The main feed pumps, of which there are usually two in each engine room, draw the water from the hot wells and feed water heaters and force it through filters on its way to the main boilers. The hot wells are simply the receptacles for the water of condensation in the condensers of the main engine exhaust steam. The circulating pumps circulate cold sea water through the tubes of the main condenser, and then discharge it overboard. These pumps, of which there are two for each engine, are usually of the centrifugal type, driven by vertical compound engines. In addition to these main circulating pumps, there is also a smaller, similar one for the auxiliary condenser, in which the steam of all the auxiliaries is condensed while the ship is in port.

The main throttle valve and the re-

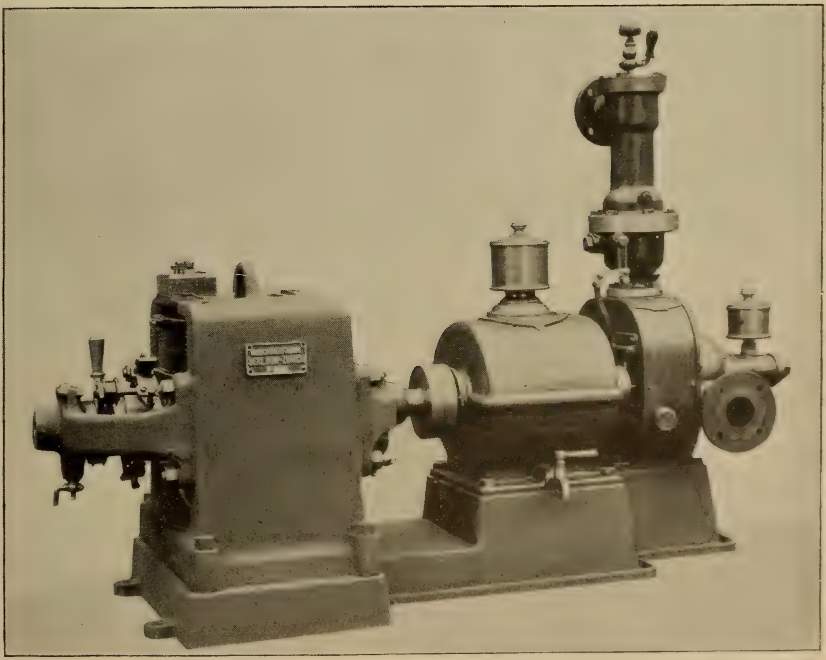


A BUFFALO BLOWER FOR SHIPBOARD USE.

versing gear of the main engines are all driven by small engines, since the manipulation of these by hand, after the practice of former years on the older vessels, would require considerable time and labor. With their assistance the large engines may be started, stopped or reversed almost instantaneously with the greatest ease. Each main engine has also a throttle governor attached. This is a contrivance to prevent them from racing when the propellers come above water in bad weather. This racing, or rapid increase in revolutions, due to the work being removed from the engines, has often been the cause of disastrous breakages to machinery. The throttle governors communicate, through a pipe, with an iron dome, bolted to the bottom of the ship at the stern, and open to the sea at that end. A spring loaded diaphragm is provided at the governor. As the stern of the ship rises or falls in the sea, the air in

this pipe is compressed or expanded and exerts a greater or less pressure on the diaphragm, causing a movement one way or the other. This movement, by means of a spindle, admits or cuts off steam to the governors, which, in their turn, open or close the main engine throttles, thus automatically adjusting the steam supply to the work being done by the propellers.

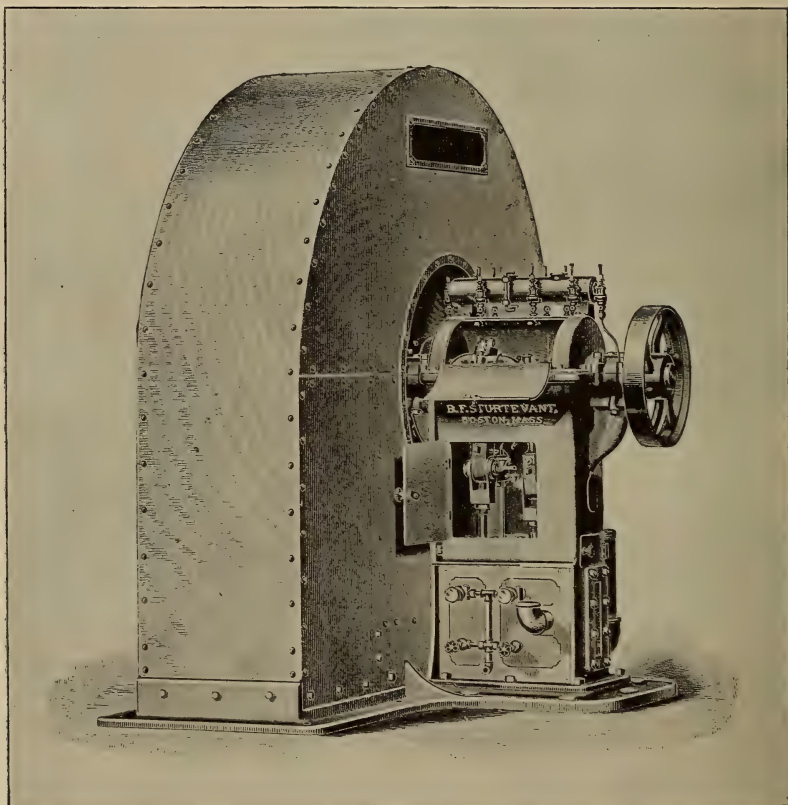
The weight of the large amount of coal burned during a trip is in excess of the weight of the cargo carried ; consequently, the gradual lightening of the vessel would greatly alter her trim and draught, and impair the conditions for fast running. To overcome this difficulty, the vessels are built with a double bottom, running, in some cases, from bow to stern, and in others, only part of that distance. This double bottom is used for salt water ballast, and also acts as a safeguard in case of injury to the bottom. The bottom is subdivided into compartments, the division plates really being the water-tight bulkheads of the vessel running from the bottom to the upper deck. These compartments are called ballast tanks, and those near amidships are again subdivided by a fore-and-aft bulkhead. These are called divided tanks, and by pumping sea water into them on either side, the vessel can be balanced, no matter how unevenly the coal is drawn from the side bunkers, or how strong the wind may be blowing on her side. A large ballast pump handles the sea water put in these ballast tanks, and any one may at any time be quickly filled or emptied, as required. In every water-tight compartment of these ballast tanks are pockets, called bilge wells. Any water, which accumulates from leakage or any other cause, finds its way to these bilge wells, from which it is pumped overboard by pumps, called bilge pumps. These bilge pumps, which are usually located in the engine rooms, have an elaborate system of piping connecting them to all the bilge wells and every place below the waterline where drainage collects and cannot flow overboard by gravity. All the bilge wells and ballast tanks



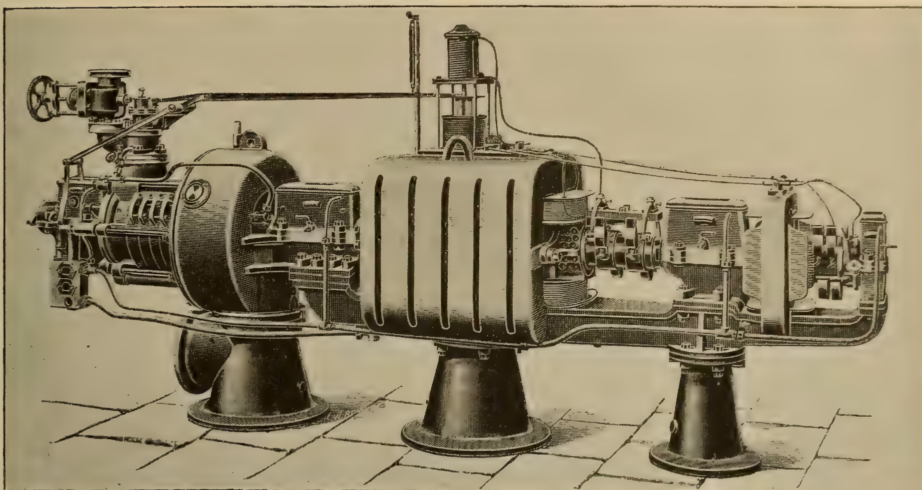
A DE LAVAL STEAM TURBINE DYNAMO.

have vertical pipes running into them, through which a sounding tool is periodically lowered to ascertain the height of water in them. In some cases the drains that accumulate under the main engines, which, of course, are of an oily nature, have a special pump, discharging them into the stern bearings, thus making them serve a useful purpose.

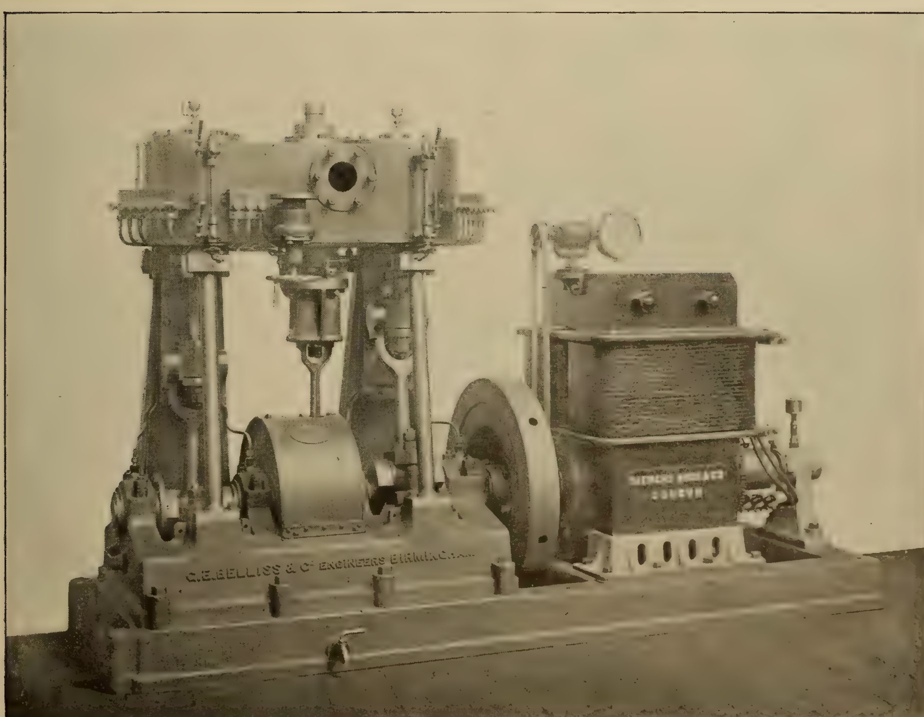
The fire pumps also are located in the engine rooms, and have pipe connections running all over the vessel, so that there is no place on board to which a hose cannot quickly be laid. This fire pipe system is in almost constant use for washing down the decks. Each cargo compartment is fitted up with special steam pipes, so that in case of fire steam may be quickly blown in to extinguish it. Sanitary pumps also form part of the auxiliary plant. These force sea water into a tank or a standpipe placed above the top deck, so that all the bathrooms and lavatories have a good supply of water under pressure. This supply is also led to all the bearings on the main engines and shafts, to cool them in case they become heated. The fresh water on board is carried in large tanks, which are carefully cemented on the inside. From these, fresh water pumps force it to a tank or standpipe similar to that of the sanitary system, and from this it is distributed in much the same way. As a great quantity of fresh water is rather expensive and heavy to carry, all modern steamers are equipped with an evaporator or apparatus for distilling sea water. The distilled water is rather insipid to drink, but serves excellently for washing and cooking. The evaporator has its own



A STURTEVANT BLOWER ON THE STEAMER PARIS.

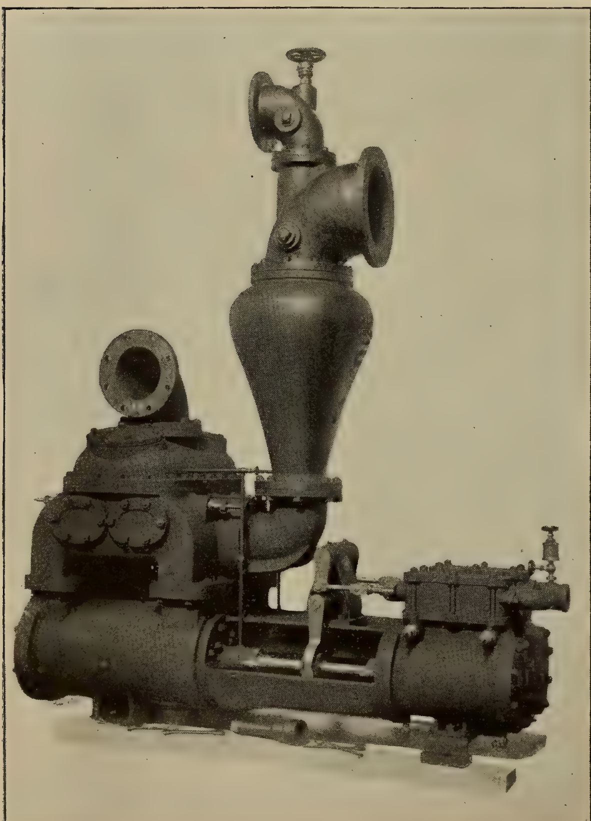


A PARSONS STEAM TURBINE DYNAMO.



COMPOUND ENGINE AND DYNAMO USED FOR LIGHTING THE CAMPANIA AND LUCANIA.

feed pump and also a delivery pump to distribute the distilled water, as in the case of the fresh water and sanitary supplies. All the pumps of importance are arranged with distribution boxes, so that, in case of breakdown of one pump, another one may be instantly connected to its system while the damage is being repaired. This can usually be effected very quickly, as duplicates of parts are always kept in stock. Furthermore, all the stems of the valves on the distribution boxes of the ballast and bilge system pumps, circulating pumps and others, have extension rods connected to them running to the decks above, so that in case the places should become inaccessible, by flooding through collision ; for example, the valves can be manipulated from above to connect the flooded compartment with the pumps or powerful ejectors.

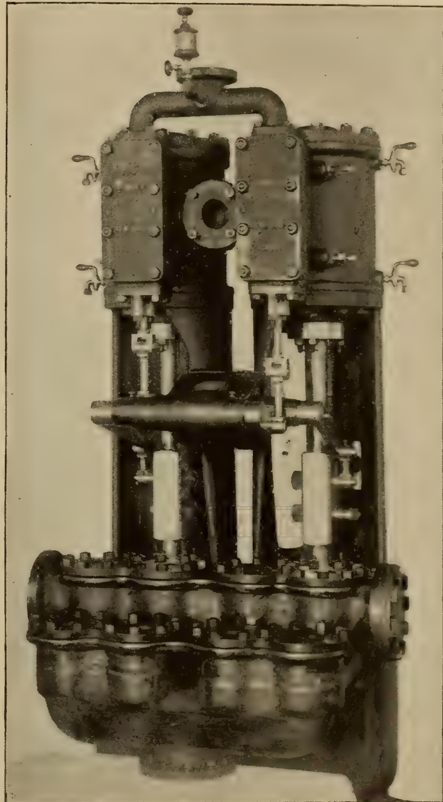


A WORTHINGTON MARINE CONDENSER.

The electric plant usually consists of from four to six dynamos, each driven by its own independent, double or compound engine, the armature shaft being coupled directly to the engine crankshaft. The dynamos are generally of the multipolar type, the armature making only from 300 to 450 revolutions, and usually run at 100 volts. This system of direct driven armatures is especially well adapted for ship lighting, since fast running belts on shipboard in heavy weather always cause considerable trouble. Compactness and economy of space is another recommendation for the direct connected outfit. In this connection it may be well to mention another direct driving system, which is growing in use for lighting vessels. This is the dynamo and steam turbine combination with which a speed of about 8000 revolutions per minute is obtained. The turbine takes up very little room, and develops considerable power. In one of its forms it consists of a shaft carrying three copper cylinders, each of larger diameter than its adjoining one. The cylinders are equipped with rows of little blades about one-quarter of an inch square. A casing, in two equal parts, which fits around these cylinders has similar rows of guiding blades, and these fit in between the rows on the cylinders. To avoid end thrust, the shaft carries a second set of similar cylinders facing the opposite way, so that when steam is admitted between the two sets, it divides itself. The steam passing the blades on the three increasing diameters expands in each case, as in the more conventional triple expansion engine. The exhausts from both ends are connected

and led to the condenser. The automatic centering device to keep the shaft central and prevent injury to the blades, as well as the lubricating gear and electric throttle governing gear, are all very ingenious. One remarkable thing about these turbo-electric generators is, that their shaft must always be placed exactly fore and aft, that is, exactly parallel with the direction in which the ship sails, otherwise the gyroscopic action will cause considerable wear on the wearing parts and seriously interfere with smooth running. The electric plant on board, in addition to driving the lights, is used to drive ventilating fans, and such auxiliary machinery which can not conveniently be reached by steam pipes. The utmost caution must be used in wiring a vessel, to prevent short circuiting and leakage. In the saloons and passenger spaces the wires run in grooves inside of ornamental wood moldings, and in other places special moldings and pipes are provided to hold them. The switchboard is arranged with a large number of circuits in much the same manner as those for city lighting.

Another important set of auxiliaries are the refrigerating machines, as most of the large vessels carry from 500 to 600 tons of frozen meat as cargo. These machines are mostly of the ammonia compression type, and are built very compactly. A single plant consists of an engine and compressor, an ammonia condenser with its circulating pump, and a brine refrigerator with its brine circulating pump. There are generally three such plants on board, one for the forward and one for the after commercial boxes and a smaller one to take care of the ship's provisions. In former years the meats for use at sea were carried in an insulated room lined with sheet lead. This was filled with alternate layers of ice and meat. At the end of a voyage the meat at the bottom would often be unfit to eat. Since the introduction of the refrigerating machines, however, the meat is just as good when taken out as when it was put in. The ship's provision box is subdivided into different compartments for milk and butter, vegetables, fish, meat, etc., so that these foods will not taint each other, and the temperature of these compartments can be regulated above or below freezing point as required. The commercial spaces are located on the deck above the hold, and there the decks overhead and underfoot and also the ship's sides are all thoroughly insulated with non-conducting material, from six to nine inches thick, consisting of double wooden sealing with granulated cork or hairfelt between. The cooling pipes are fastened overhead in these spaces, and the brine pumps circulate the artificially chilled brine through these pipes, keeping the temperature down to six or eight degrees below the freezing point.



WORTHINGTON FEED PUMPS ON THE STEAMERS PARIS AND NEW YORK.

The steam heating plant of an ocean

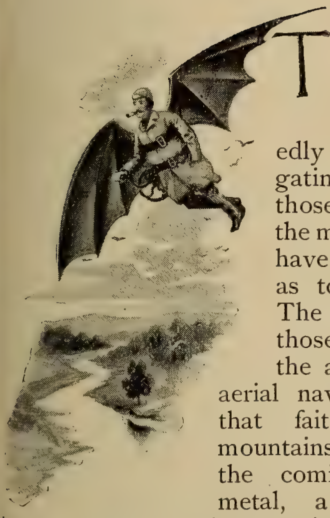
flyer is of a very elaborate kind, and includes not only the heaters in the saloons and great number of other rooms, but also heaters for the water to the bath tubs, to the hot presses in the pantries where food is kept warm before serving, to the steaming and boiling apparatus in the galleys, and to urns for steeping tea and coffee, etc. The drains from every heater and the exhaust from every engine is led back to the boilers, so that not a drop is wasted. In former years the supply of fresh air below decks depended mainly on the amount that blew down the ventilators, and in heavy weather when these had to be closed to prevent water from running down, the air below assumed a state which can be better imagined than described. On the big liners nowadays every room has a fresh air pipe running to it with a register to regulate the supply, which is constantly being driven in by powerful rotary fans, worked either by steam or electric power. On some vessels the vitiated air is drawn from the rooms by having all the air pipes terminate in the space between the two casings of the smokestacks, where the heat causes a rapid upward current. Many of the spaces above the water line have openings through the ship's side with an iron casing around them on the inside, so arranged that when a wave strikes the opening it automatically closes valves connected to it for the time being, and instantly opens again when the wave recedes. In case of derangement, which is a great rarity, the openings may be quickly closed by screwing down the watertight lid to the casing.

In addition to the ventilating fans, some of the vessels, having some system of forced draught, carry a number of large rotary fans, each connected directly to engines of about 20 to 25 horse-power apiece. The ashes are raised from the stokeholds by lifts, each having its own engine. Sometimes these lifts are run by hydraulic power. Other lifts are those from the different galleys to the saloon pantries, from the meat house to the butcher shops, and from the storerooms to the galleys. The necessity of these latter is very apparent when one considers the amount of food necessary for from 1000 to 1200 passengers and the crew.

Of the steering engines, a great variety of designs are used. All of them are easily manipulated from the bridge, and all have some kind of pneumatic buffer or brake, so that when a sea strikes the rudder it will give somewhat and ease the blow and again immediately assume its original position. There are, moreover, two turning engines used in port to slowly revolve the shafts of the main engines and put them in different positions for overhauling the moving parts. The warping windlasses on deck are used to draw the vessel into position alongside the pier on arrival. These, with the powerful anchor windlass, capable of handling the large seven-ton anchors, and the cargo hoisting winches at every hatch, about complete the list of auxiliaries. The whole story of the important part which they play in the make-up of an ocean steamer is, in a measure, told by their number, ranging, as it does, from about 50 to 100, large enough, surely, to command a little more than passing attention.

PRACTICAL FLIGHT.

By C. E. Duryea.

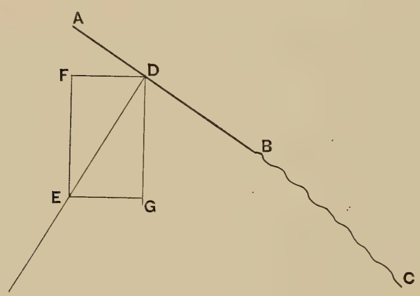


THOSE best informed concede that mankind will undoubtedly succeed in navigating the air, but only those who have given the matter special study have any distinct ideas as to how or when. The greater number of those who believe in the accomplishment of aerial navigation have not that faith which moves mountains, but are awaiting the coming of a lighter metal, a more powerful motor, an improved storage battery or some other device which is yet to be supplied before success can be attained. Even the minority who are best informed have not agreed as to the best method of carrying their views into practice, nor as to whether the balloon or the kite, modified in each case to resemble fish and bird, is the better device to adopt.

Is it any wonder then that the energetic, level-headed business man has not taken hold of the problem? It is an easy matter to compute the lifting power of a cigar-shaped balloon, estimate its resistance and required driving power and show conclusively that it may carry motors, fuel and a useful load at a moderate rate of speed, but wherein is the advantage? Or it may be figured out that inclined planes may be made large enough to support at high speed large loads, but until the business man is assured that a machine can be profitably handled he will not risk a large cost. It is not enough to show him that the air can be navigated. Before he pays the bills he must be shown that it can be done with a profit proportionate to the risk. This means that we must show him a commercially practical machine. What will it be? Not a balloon, for balloons are bulky, costly, easily damaged and positively helpless in a squall. They offer a large resistance with a given load and are not likely to be speedy. The dirigible balloon has been the subject of numerous and careful experiments by the French and their Government and a result of 14 miles per hour only has been attained with the balloon La France. Truly a small achievement, valuable though it is, for a large expenditure! French inventors are now at work on other plans promising a speed of nearly twice that of La France, but even that would be too slow in these days of a mile a minute railroad trains. If they be successful in securing a speed of 25 or 30 miles an hour, their devices will be still largely at the mercy of the wind and, therefore, not commercially practical affairs; and even if by larger sizes and increased power a greater speed should be obtained, the machines would still be commercial failures because of their great cost and frailty.

Most decidedly the principle of buoyancy is not the correct one. We admire the ingenuity and determination of Giffard and those who followed him in developing it, but their experiments have proven conclusively that it will never be commercially successful even though it might be of great value in special cases such as might occur in war. Nor would a combination of balloon and kite, as often proposed, be of value. One requires high speed to be valuable, and the other cannot be so driven. To the kite or aeroplane, then, must we look for our solution. The balloon is but little more than a

century old, but the kite is older than history. People became wildly enthusiastic when the balloon was invented, but the kite has been overlooked and regarded as a toy suitable for children only, when, in fact, it contains the elements of the flying machine



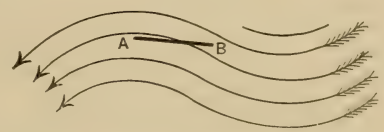
A KITE DIAGRAM.

and is now being studied by many experimenters who recognize its direct bearing on the subject. Kites are of many kinds and shapes and may be built of almost any material and of all sizes. They are usually flown with a single string but may be veered to either side and caused to rise and fall by the use of several strings. When held by a single string, the surface stands perpendicular to the string proving conclusively that the pressure of air on a plane is normal to the surface regardless of the angle of the plane. This being the case, and making no allowance for the weight of the kite, the pull on the string represents the lift and drift of the kite, and may be resolved into those two forces by causing the string, where it leaves the kite, to represent the diagonal of a parallelogram whose sides are parallel to the wind and vertical. To the lift add the weight of the kite and string and the total represents the carrying power. From the drift subtract the drag of the tail, if it has one, and the remainder represents the power needed to hold the kite itself against the wind or to propel it through air. In the diagram on this page let A B represent a kite, with a tail B C and string D E. Then D F represents the drift, and D G the lift. In a well-flying kite, the lift will be from 12 to 15 times the drift. These facts are easily understood and proven. To have a flying machine, we have but to make the kite so large that it will carry the flyer and his motor and machinery and see that the motor is powerful enough to cause a screw, or other propeller, to exert a pull on the air equal to the drift. There is no question about our ability to do this. Kites have often been made large enough to support a man.

About 1825, Pocock, an Englishman, patented a kite having several strings which were used to make it rise and fall at will or to veer to either side. Pocock narrates that on several occasions persons were lifted to a considerable height by kites of his design. To lift such a load with a kite presents no difficulty worth mentioning, nor does the use of a motor to supplant the string change the conditions. If anyone thinks differently let him try this experiment. Fix two strings to the kite, one to be carried forward to a tall pole or to the string of another kite, and the other to hang downward and be loaded. Here we have the lift and drift separated, but the action of the kite is not changed. Many will doubt the ability to make a motor powerful enough to drive the kite that is to carry it through the air at the required speed, but such engines are now in use and lighter ones yet may be constructed. Various experimenters have proven that one horse-power applied to a screw will exert a direct pushing force of 33 pounds. The power equipment of the steam yacht Norwood weighs only 19 pounds per horse-power and is therefore more than powerful enough to lift itself, but the builder, Mr. Mosher, stated at the Aerial Navigation Congress in Chicago last August, that the weight could be reduced to 10 or 12 pounds per horse-power, if designed for aerial use. Builders are also awaking to the fact that a gallon of ordinary gasoline, weighing about five pounds, will develop a horse-power for ten hours when used in a gasoline engine and that such engines may be both simple and light weighing probably under 10 pounds

per horse-power. The simplicity of the gasoline engine and the compactness of its fuel render it likely to be the popular motor in future for all work requiring light weight. We may therefore build a kite and provide it with a driving device and use it as a flying machine with the same certainty that we now build a bicycle, or a boat. The cost is not great nor will there be any expensive and uncertain experimenting. Neither need there be any serious danger to the learner. The kite flyer knows that if his kite has sufficient tail it will not "duck," and that so long as it will not turn over it will fall very lightly; also that if the wind slacks sufficiently his kite will fall and *vice versa*. With our motor we may have this matter under control. Need more be said to show the certainty of our ability to fly? Surely not!

But while the proposed kite will certainly fly, it will be far from perfect. It should have a rudder instead of a tail. Where is the boatman who would attempt to steer his boat by trailing a lot of drift-wood behind it? The tail adds to the stability of the kite but at the expense of power. Practice with a rudder will give better results. The angle is bad. Most kites present themselves to the wind at angles of from 15 degrees to 30 degrees, and thus would require a much more poweful motor than if they stood at an angle of from 2 degrees to 5 degrees. This great angle adds to their stability, but practice will enable the flyer to manage them at the lesser angles. The shape, further, is bad. Experiments show that a long and narrow wing gives better results than a short and broad one as exemplified by the usual form of kite. The kite, however, is stable and in our novitiate days we cannot afford to sacrifice stability to save power. When we have acquired a proficiency such as the skater and cycler possess we may merge the kite into the perfect flying-machine by using very narrow planes superposed. By such an arrangement, sufficient surface to support a man may be carried and yet the machine need not be too large to start and alight in an ordinary roadway. Our kite should be large enough to form a decent parachute, but then such an appliance will be considered useless. We expect and intend to carry a large amount of power, but we will take advantage of the wind and traverse the air in all directions with energy derived from it and need no motor whatever. To many the thought of doing this seems foolish and it is classed with the perpetual motion and philosopher's stone ideas. This is not proper, however, for the soaring birds soar at will without the expenditure of any appreciable energy, and we may do likewise. That this is possible is easily understood when we consider that the wind is not a continuous steady current, but undulates and pulsates in many directions, and by taking advantage of these variations the bird propels itself. To illustrate this let us look at a supposed vertical section of the atmosphere as indicated in the diagram below. All winds are more or less undulatory. We therefore indicate the current by the wavy arrows. To the observer on the earth's surface the wind is a succession of calms and gusts, but to the bird it is a succession of rising, falling and horizontal currents. The bird presents its wings to the current of air at a very small angle, say, of about 2 degrees.

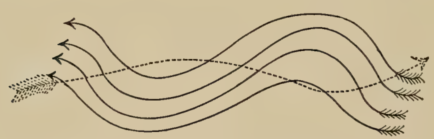


VERTICAL SECTION THROUGH ATMOSPHERE

It is evident therefore that if the wind be rising more than that amount, the bird will be able to remain in the air by the aid of energy derived from the wind, for with such a wind its wings may present their proper angle to the current and yet may be inclined toward the earth as the line A B. Such an inclination would cause the bird to be urged forward or lifted upward or both; and the bird may prolong this action till it secures such height or speed as it desires by directing its motion parallel to

the crest of the wave, and then it may circle so as to cross the parallel and descending portions of the current quickly and at great speed, and thus avoid much loss of either height or speed, and finally repeat the action on the next ascending portion. The undulations mentioned are often hundreds of feet apart, as any observer may note by watching the gusts of wind, and form one of the causes of a kite "ducking," due to a lifting of the tail, so that it is no longer properly ballasted. With proper management of the kite-flying machine it may be driven forward by the same gust that "ducks" the ordinary kite.

Besides these undulations there are others that may assist the bird and the flying machine. Let the diagram below represent a horizontal section through the air, the arrows showing



HORIZONTAL SECTION THROUGH ATMOSPHERE.

the direction of movement. That such a movement does often occur may be determined by watching a line of smoke, or the folds of a flag. Imagine the bird to be a sail boat, and it is plain that it can tack so as to advance against an undulating wind about as shown by the dotted arrow. The bird by rolling sidewise can lift one wing so as to permit it to act as a sail and its inertia will keep it from being blown greatly to one side for the brief instant that it is passing through one portion of an undulation. The next undulation, striking from the other side, has to overcome the previous motion and inertia before causing a drift. Now when we remember that the bird offers but little resistance to motion in the plane of its wings and much resistance to motion in other directions, it is not hard to understand how it may derive from the air that strikes the wings at a decided angle of impact sufficient energy to drive it through the air that meets only the forward edge resistance. Whether we will ever be able to take advantage of this form of undulations is not for the writer to say, but it is likely that we will. The bird's wings stand at an angle to each other, and a side wind tends to lift the proper one without action on the part of the bird. It is probable that our flying machine may be so constructed as to automatically accomplish this.

As a further evidence of what is possible in this line, some very interesting experiments are to be found noted in Mr. Octave Chanute's articles on "Progress in Flying Machines," which have appeared in The American Engineer. "One especially remarkable," as there stated, "is that of Le Bris, a French mariner, who, by observing the albatross and experimenting with a wing of one of these birds, believed that he had discovered the secret of soaring flight and constructed an aeroplane on corresponding outlines, measuring about 50 feet from tip to tip, with about 250 square feet of surface and a weight of 92 pounds. He had a means of controlling the angle of the wings and tail and his expectation was that with a strong wind, he would rise into the air and reproduce all the evolutions of the soaring Albatross, without any flapping whatever. Le Bris's first experiment was conducted on a public road at Trefeuntec, near Douarnenez, Betieving. That it was necessary for the apparatus to have an initial velocity of its own, in addition to that of the wind, he chose a morning when there was a a good 10-knot breeze from the right direction, and setting his artificial albatross horizontally on a cart, he started down the road against the wind, the cart being driven by a peasant. The bird, with extended wings, was held down by a rope passing under the rails of the cart and terminating in a slipknot fastened to Le Bris's wrist, so that with one jerk he could loosen the attachment and allow the rope to run. He stood upright in the body of the machine, unencumbered in his movements, his hands being on the levers

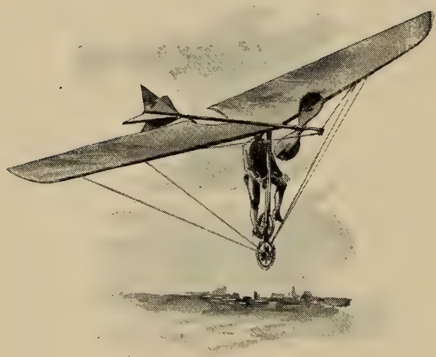
and depressing the front edge of the wings, so that the wind should press upon the top only and hold them down, their position being, moreover, temporarily maintained by assistants walking along each side. When they came to the right turn in the road the assistants were directed to let go, and the driver was told to put his horse on a trot. Then Le Bris, pressing on his levers, slowly raised the front edge of the wings to a very slight angle of incidence. They fluttered a moment, and then took the wind like a sail, on the under side, relieving the weight upon the cart so much that the horse began to gallop. With one jerk Le Bris loosened the fastening rope, but it did not run, and the bird did not rise. Instead, its ascending power counterbalanced the weight of the cart, and the horse galloped as if at full liberty. It was afterward ascertained that the running rope had been caught on a concealed nail, and that the apparatus had remained firmly fastened to the cart. Finally the rails of the latter gave way, the machine rose into the air, and Le Bris said that he found himself perfectly balanced, going up steadily to a height of nearly 300 feet, and sailing about twice that distance over the road. But an accident had taken place. At the last moment the running rope had become wound around the body of the driver, had lifted him from his seat, and carried him up into the air. He involuntarily performed the part of the tail of the kite, his weight, by an extraordinary chance, just balancing the apparatus properly at the assumed angle of incidence, and with the strength of the brisk wind then blowing.

"Up above, in the machine, Le Bris felt himself well poised in the breeze, and exulted that he was about to pass two hours in the air; but below, the driver was hanging on to the rope and howling with fright and anguish. As soon as Le Bris became aware of this state of affairs, and this was, doubtless, in a very short time, he took measures to descend. He changed the angle of incidence of his wings, came down slowly, and manœuvred so well that the driver gently reached the ground entirely unharmed, and ran off to catch his horse, which had stopped when it had again felt the weight of the cart behind. But the equilibrium of the artificial albatross was no longer the same, because part of the weight had been relieved, and Le Bris did not succeed in reascending. This exploit naturally caused a great deal of local talk."

While this experiment contains nothing that cannot be closely duplicated with a well-made kite, it is both interesting and convincing in that it demonstrated that man may soar as the birds do. The height reached with two men aboard shows that a great surface is not necessary and that there will be no difficulty in soaring till the next upward trending gust. The distance covered is evidence that the machine was actually deriving power from the wind. Le Bris afterward made a number of other attempts, which, while starting fairly, usually ended disastrously, showing plainly that the necessary skill was lacking.

In 1883 M. Gaupil built a machine having about 290 square feet of surface, which in a thirteen-mile breeze is said to have lifted itself and two men, a total weight of 440 pounds, while the drift was less than 18 pounds. This machine was not free, but was confined by ropes to the ground so that the ascending currents could not act on it, and it would therefore seem to be a fair example of the results to be obtained from horizontal winds. If we consider it as such, we may infer that a machine for a single rider with a total weight of half the above would have a drift of less than nine pounds, or about one-quarter of the push which we may derive from a horse-power, and as a man may develop a quarter horse-power for short periods, we have reason to believe that a bird-like machine, having a surface of from 150 to 200 square feet, and weighing with rider from 150 to 200 pounds, could be driven a short distance through calm air by the rider, if provided with a propeller worked by gear-

ing through foot-power. In 1884 De Sanderval experimented with an apparatus spreading 300 square feet of surface. This he suspended from a cable stretched between two bluffs and found that a light wind caused the apparatus to swing to one side till the suspending rope became horizontal and the



A SUGGESTION FOR A FLYING MACHINE.

air carried the weight, in which position the machine would oscillate at the will of the operator. Need there be any doubt about his ability to fly if his apparatus had been provided with a motor and propeller sufficiently powerful to overcome the drift as did the rope ? He further states that with a wind of from 18 to 22 miles an hour the additional weight of two assistants was sustained. He also states that the surface was enough to sustain a man at a slow rate of fall, a point to be remembered with our first machines. He tried swinging when suspended by a single rope, but says that his rope was too short to permit gaining the proper speed. A longer rope would permit a larger circle and give the operator a chance to acquire a higher speed and to manœuvre more freely, and until one gains a skill that is almost a second nature he will need much time to think how to act. The writer called attention to this necessity in a paper on "Learning How to Fly," read before the Aerial Navigation Conference at Chicago last August, and pointed out that a captive balloon, anchored by several widely divergent ropes, offered the best means of securing a long, free suspending rope on the lower end of which the man and machine could practice with perfect freedom and safety.

On a small scale, but with encouraging success, M. Moulliard, of Cairo, Egypt, has experimented with the simplest of aeroplanes, without motor of any description, believing it possible to sail indefinitely upon the wind without flapping. He describes one of his attempts at soaring as follows : "Near by there was a wagon road raised some five feet above the plain. It had thus been raised with the soil from ditches about ten feet wide dug on either side. Then came a little puff of wind, and it also came into my head to jump over that ditch. I used to leap across easily without my apparatus, but I

LEARNING WITH A BALLOON.

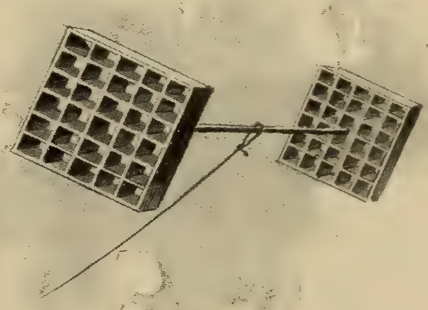
thought I might try it armed with my aeroplane, so I took a good run across the road and jumped at the ditch as usual. But, oh horrors, once across the ditch, my feet did not come to earth ; I was gliding on the air and making

vain efforts to land, for my aeroplane had set out on a cruise. I dangled only one foot from the sail, but do what I would, I could not reach it, and I was skimming along without the power to stop. At last my feet touched the earth, I fell forward on my hands, broke one of the wings and all was over, but goodness, how frightened I had been! * * * I then measured the distance between my toe marks, and found it to be 138 feet.

"Here is the rationale of the thing. In making my jump I acquired a speed of eleven to fourteen miles per hour, and just as I crossed the ditch I must have met a puff of the rising wind. It probably was traveling some eight or eleven miles per hour, and the two speeds added together produced enough pressure to carry my weight."

Had he been high enough to have not landed till the next gust, he might have been again lifted and had continuous flight, provided, of course, that his skill had been sufficient to enable him to adapt himself and machine to the varying gusts. In the same line are the experiments of Herr Lilienthal, of Berlin, Germany, who during the past two or three years has been practicing with planes too small to support him, but large enough to teach the management, in the hope that he might increase the size of his plane as he developed skill. His device is bird-shaped, with wings and tail, has a spread of 86 square feet and a weight of 40 pounds. His method of practice is to find a hill sloping toward the wind, across the top of which he runs, jumping into the air at its brow. Then he glides forward and down for some 70 or 80 feet. This is a very interesting feat and well worthy of imitation did we not possess in the captive balloon a means of practicing with a full sized machine in perfect safety and in a better strata of air.

Another experimenter well worthy of mention is Mr. Lawrence Hargrave of Sydney, N. S. W., who has built 18 different models of increasing size and made them all fly various distances, the greatest being 512 feet. These are not simply soaring machines, but are planes provided with motors and propellers. His motors include rubber bands, compressed air and steam engines, and for propellers he uses both the wing and the screw with seemingly good results. Nor does his work stop here. He has produced some kites that meet the requirements of the flying machine more nearly than any with which the writer is acquainted. In principle they are two planes, one at each end of a stick, with a single string attached to the stick slightly in front of the middle. In practice, he superposed the planes, making in one form a bunch of pigeon holes with the stick projecting from the middle. These



HARGRAVE'S KITE.

kites had no tail and, using narrow planes, flew with a greater lift and less drift than the ordinary kite. In that respect they are excellent models to copy in our first machine were it not that we need a goodly surface to insure a slow fall in case of accident while practicing. Mr. Hargrave makes each new model larger than before and the success which he has had would indicate that the necessary equilibrium is not difficult of attainment if one goes about it right, although most experimenters have failed on this point.

If a machine will automatically preserve its equilibrium under good conditions, it would seem that an intelligence should easily learn to assist it through the rough places. The partial

successes in flying experiments were such because of favorable conditions. The weight, angle and wind were properly proportioned to each other. That these successes were short-lived and ended disastrously does not prove flying difficult. It proves only that a constant adjustment of balance is necessary. We constantly do this in walking, skating or cycling and can do so in flying with a little practice, as set forth in the writer's article referred to above. This lack of skill alone stands in our way. Every other point has been tried and proven in our favor. We have but to build our machine and practice with it, and success will be ours. The pioneer machine will, in all probability, be a large kite-like affair, with ample surface and even more ample power in the shape of a gasoline motor and screw propeller. It will be provided with a means of guiding both up and down, and sidewise. It will carry but one operator, who must feel that the machine is almost part of himself. Its speed will be small, probably from 15 to 25 miles per hour, and its angle will be great because of increased stability. Its cost need not be more than that of a small steam launch, while its greater speed and ability to go anywhere will commend it to enthusiastic athletes everywhere.

The art of balancing once learned, and fear allayed by usage, improvements will follow. The angle will be decreased and the speed increased. Superposed planes, compactly arranged, will permit and require higher speeds. Increased experience and our superior intelligence will enable us to surpass the birds in their own element. Professor Langley thinks ninety or one hundred miles per hour not improbable. The increased skill, due to a regular use, would probably enable a flyer to manage a machine without the aid of a motor or, at most, with such assistance as his own muscles afford. Such a machine need not cost greatly more than a first-class cycle. Busy New Yorkers could spend their nights in the Catskills, and their holidays in the White Mountains. Pleasure seekers would find it the most agreeable method of travel. Its high speed, its universal application, its freedom from the common causes of accident such as snags, washouts, broken rails, burnt bridges and collisions, and its cleanliness would combine to make it a popular means of transit. Fifteen years marks the history of the bicycle as it grew from an athlete's means of amusement to the busy man's vehicle. Half that time has seen the electric street car displace the horse. Is it unreasonable to think that before many years, the flying machine will have placed itself by their side as a means of transit? With a public not only awaiting such an invention but always eager to increase their speed of travel; and an article that will advertise itself as nothing before was advertised, the business man has but to offer the goods and reap the reward.

CONDUIT ELECTRIC RAILWAYS.

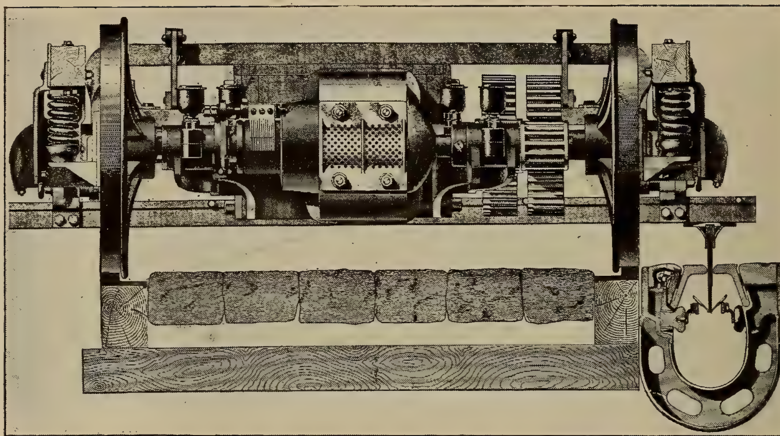
By Joseph Sachs, Assoc. Mem. Am. Inst. E. E.

AMONGST the various practical applications of electricity that have contributed so greatly to the advancement of this electric age, the electric railway is certainly pre-eminent. It may well be said that this most promising branch of applied electricity has been most exceptionally successful, notwithstanding that it is but ten years since the first electric railway was commercially operated in the United States. Considering that today there are hundreds of miles operated upon a commercially profitable basis, and in competition with other means of car propulsion, the growth of the electric road has certainly been most phenomenal.

Early in the development of electric traction, the advisability of either making the car self-contained or conveying the electric current to it from some source underneath instead of above the car had been recognized, but up to the present day the vast majority of electric street railways are operated by the overhead wire method. Although dozens of experiments and trials have been made, both in this country and abroad, with the storage battery, and also with various conduit methods, neither of these seem to have yet been able to fulfill the requirements for a successful system of electric street car propulsion. In the United States, aside from a trial of the conduit on a commercial basis at Washington, D. C., not a single road operated by either of these methods is in successful operation; but it seems that both methods have met with slightly better success in Europe. The latest attempt at storage battery traction at Birmingham, England, is said to have shown the storage battery to be an efficient competitor with other methods of traction. At Blackpool, England, and at Buda Pesth, Hungary, the open slot conduit with a continuous, bare trolley wire supported in it, has been in practical and commercial operation for quite some time.

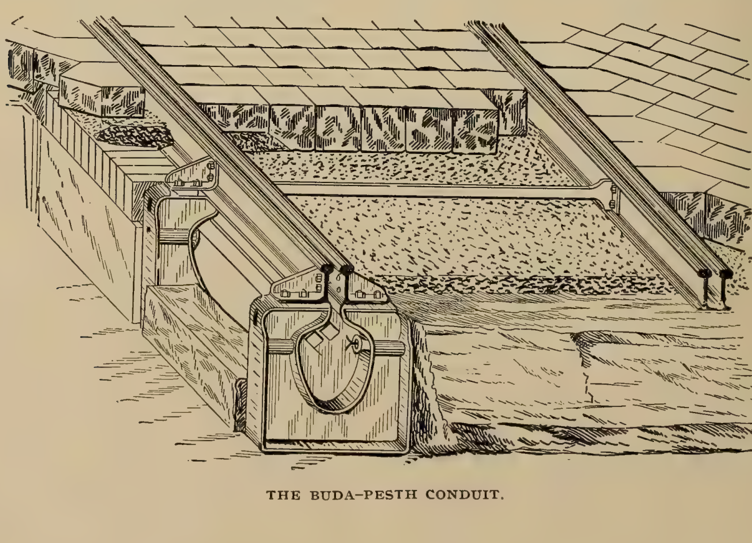
Considering the rapid growth of the electric railway and the incessant cry of "deadly trolley," raised whenever an attempt is made to introduce the overhead system in any city, and the various real objections inherent in the overhead trolley method, it would certainly seem that there is a most urgent demand for some method in which these various difficulties and objections—both real and imaginary—would be overcome. That this demand is one that cannot yet be satisfactorily met, upon a commercial basis, seems to have been the general impression. With the storage battery this is undoubtedly true to a great extent. The many experiments and actual trials made with storage battery traction, have shown that with present forms of battery the self contained electric car must remain a thing of the future. The principal objections appear to be the excessive weight necessary, inability to stand sudden strains, as in starting, destructibility, and cost of maintenance and repair. For the present we must confine ourselves to methods in which the electrical energy is generated in central power stations, and conveyed to the car by means of conductors or wires in various forms.

The idea of supplying the electric



A BENTLEY-KNIGHT MOTOR TRUCK, CONDUIT AND PLOW.

current to the motor on the car from a rail or wire placed upon the ground adjacent to the tracks appears to have been embodied in some of the very first experiments and trials with the electric motor for car propulsion. The impracticability of such an arrangement was, however, demonstrated, as soon as it was attempted to use this plan in actual street railway service. The necessity for properly insulating the conductors prevented the use of any such arrangement, except at extremely low voltages, or upon special or elevated tracks. It appeared, however, that the contact or working conductors could readily be placed in a slotted conduit, or trough, located adjacent to the track, and connection made between the wire and the motor by an arm projecting down through the slot. In fact, two of the first electric railways ever operated on a commercial basis were supplied with current in this manner. The Bentley-Knight road at Cleveland, O., was opened in 1884, and operated for about a year or two, and the road at Blackpool, England,—an open conduit road,—installed in 1885, is operating efficiently at the present time. There is now only one other open conduit road in actual commercial operation,—that

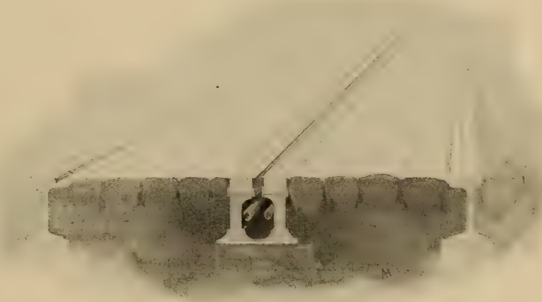


THE BUDA-PESTH CONDUIT.

at Buda-Pesth, consisting of between six and seven miles of double track and about sixty cars. The latter road has been in daily operation since 1890. It appears, however, that the location of these roads has been a prime element toward their success. Although repeated attempts have been made in the United States with an open slot conduit of similar design to that used in Europe, the conditions seem to be more severe, and it is doubtful whether a reproduction of either of the above roads located in an American city would prove successful. The last attempt in the United States to solve the problem with the open slot conduit and continuous, bare wire has been at Chicago, Ill., and Washington, D. C. The Love conduit system, which was installed in both places, has been, from latest reports, quite successful, particularly at Washington. This system, although following the same general lines as previous conduit systems, has been designed with a somewhat better knowledge of the problem. The Washington road is at present being quite continuously operated.

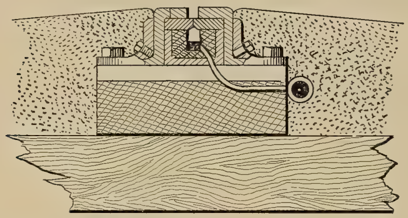
It is astonishing to note the many forms of open slot conduits that have been devised. All of them embody a slotted trough, or conduit, running parallel and adjacent to the tracks, with the necessary contact wires supported inside upon proper insulators. The current is supplied from a central source, and the wire is continuously charged along its entire length. In some of the forms the circuit is made up of one wire in a conduit and the track, in some two separate wires are used, and in others practically two conduits, each containing a single wire, are employed. Some systems have also been devised in which the propelling motor is located in a large conduit instead of upon the car truck. The main object, however, appears to be to shield the wire from the influence of moisture and mechanical injury, and in most of the plans devised precautions are taken to guard against injury or disturbance from these causes. In one or two methods, that have been devised, the inventor, in order to make sure that no moisture would collect on or about the conductor, provided a hollow tube which supplied the current and which was kept at a high temperature by a heating medium circulating in it.

The writer is of the firm belief that an open slot continuous wire conduit can be devised that will be commercially practical and efficient, and at a cost which will certainly compare favorably with the cable. The main difficulty with conduits that have previously been experimented with, appears to have been the extremely meagre dimensions, bad location of the contact wires, and lack of proper drainage facilities and of protection of the wires from moisture. With a properly designed conduit, of ample dimensions and good drainage to start with, it would certainly appear to be within the powers of electrical engineers to so locate and insulate the wires as to keep them in proper working condition. The voltage or pressure used on the wires is, however, a most important item to be considered. In the various unsuccessful trials with the conduit it has been the practice to use very nearly the same pressure as that of the overhead system. This should be very much reduced. The conduit roads in actual operation are using only 300 volts or thereabouts. With even a



THE BLACKPOOL SYSTEM.

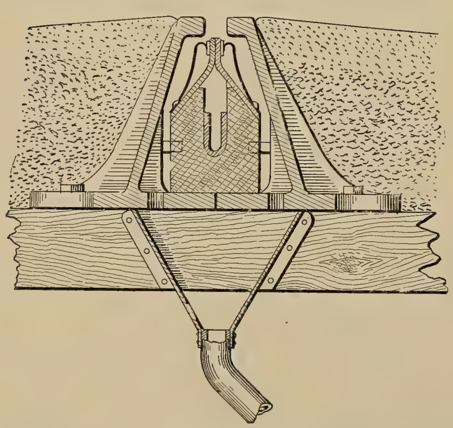
lower pressure success can certainly be more readily obtained. With a direct current this could not very readily be accomplished without a large outlay in copper. It would appear, however, that some alternating current



VAN DEPOELE'S CONDUIT SYSTEM, WITH FLEXIBLE LIPS.

method of distribution could be devised which would be particularly fitted for this purpose, if a practical motor could be produced.

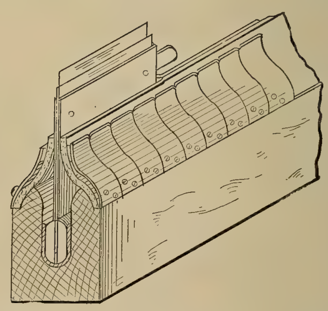
But inventors have not confined themselves to open slot conduits. A large variety of modifications of the open conduit and other plans have been patented to meet the conditions that the various forms of open slot conduit have thus far been unable to fulfill in all but the few cases mentioned. Most of these have been on paper only,



ANOTHER VAN DEPOELE FLEXIBLE LIP CONDUIT.

and in the form of models, while the various plans that have been actually tried have appeared even less capable of meeting the severe conditions of every-day street railway service than the open slot, bare wire conduit, and none of these plans have seen even partial commercial success. Some of these systems are highly ingenious and may be developed to commercially practical conditions; most of them, however, are of a rather dubious practicability.

The difficulty of keeping the open slot conduit clean, and the advisability of having the bare conductors thoroughly protected has caused the invention of plans and devices in which the slot of the conduit containing the wires is normally closed by flexible or movable flaps or shutters which are opened or pushed aside by the trolley or contact carriage. The Van Depoele conduit represents one type of such construction. In this plan the conductor

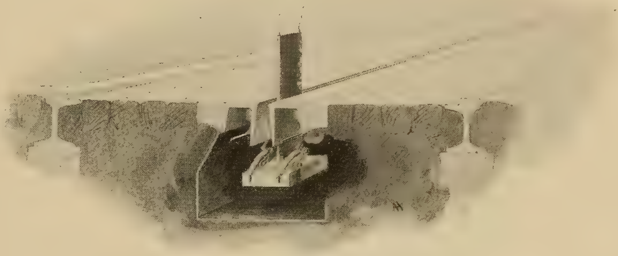


DETAIL VIEW OF VAN DEPOELE'S FLEXIBLE LIP DEVICE.

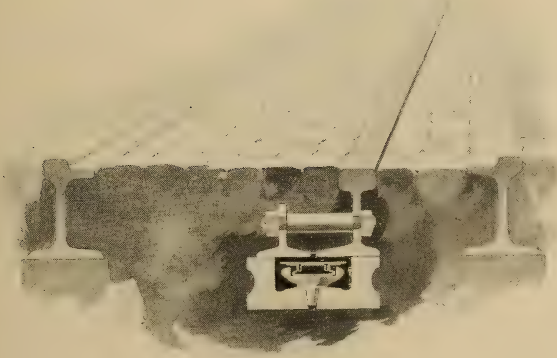
is placed in an insulating trough of small dimensions, normally closed by flexible insulating lips. The contact device pushes the lips apart as it proceeds along the road, and they automatically close over the conductor again after the car has passed. In another plan devised by Mr. Van Depoele similar devices are applied inside of an ordinary slotted conduit. Other plans have also been devised in which metallic shutters automatically close over the slot after the car has passed, and in some systems the conduit is divided and the part containing the wires is protected by movable shutters or flaps. Although such slot-closing devices would aid in the efficient operation of the ordinary conduit, it is extremely doubtful whether any method

could be devised that would be mechanically practicable.

In order to overcome some of the difficulties of a slotted conduit system, inventors have attempted to entirely eliminate the slotted conduit and place the working conductors upon the surface of the street between, or adjacent to, the tracks. As previously stated, this was one of the first methods which the early inventors of electric railways considered. As it would be utterly impossible and impracticable, however, to place a continuous, bare, charged conductor on the surface of a street, various methods have been devised to have the contact conductor normally out of connection with the source of supply and have only that portion charged which is directly beneath the moving car. This is accomplished by dividing the contact conductor into numerous sections. The contact sections are automatically connected with the insulated feeding conductor as the car advances, by electro-magnetic devices, located in, or adjacent to, the road bed. The contact sections, or points, are so arranged that the collecting devices on the cars are always in contact with a new section before leaving the preceding one, so that each section is automatically connected with the feeder through the medium of the switching device, which is actuated by the current derived from the preceding section; and after the car has passed the connection between the contact section and the feeder is automatically broken.



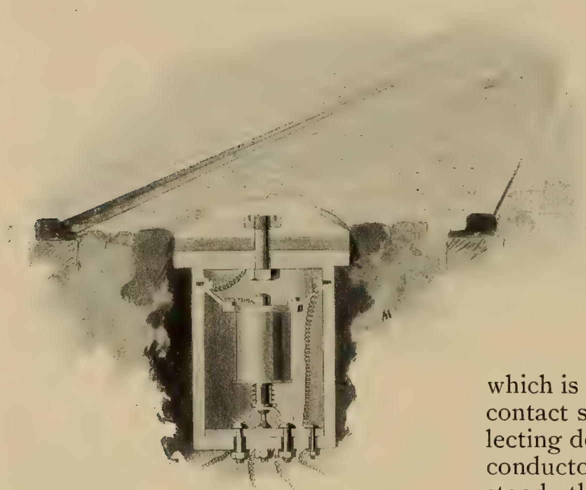
THE LOVE SYSTEM.



THE LINEFF SYSTEM.

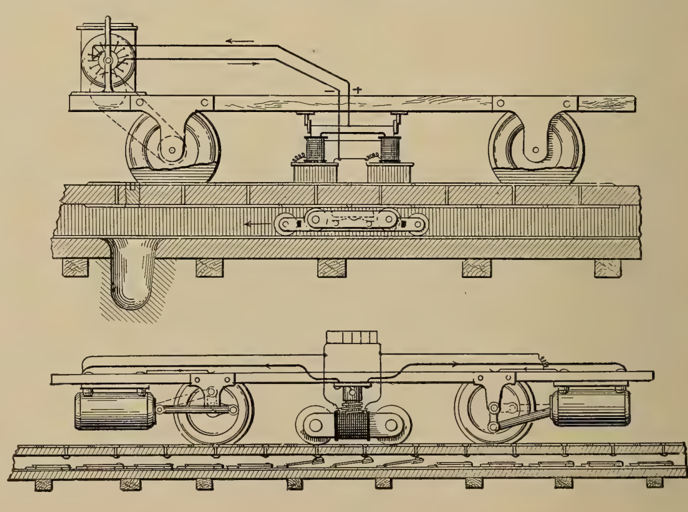
Although it has been stated that the operation of a system in which the current was supplied to the car by a continuous bare conductor laid upon the surface of the street, would be impractical and impossible, such arrangements have been devised and, in fact, Edison some time ago devised and patented a system of surface contact in which the rails formed the working conductor. At any high voltage this would certainly be impracticable, but it was intended to transmit electric current from a source of supply at fairly high voltage and transform it to an extremely low voltage (about twenty volts) by means of motor or other transformers located in manholes along the line of the road. The rails were to be supplied with this extremely low voltage current, and it was argued that, the pressure being so extremely low, no danger could arise from the continu-

ously charged rail, nor could any damage be caused by connecting the two opposite rails. The wheels of the car were to be insulated from the axle and large brushes were to make contact with the rails. The enormous amounts of current which it would be necessary to convey to the car, and the immense cost of construction and maintenance would entirely prohibit the operation of such an arrangement upon a commercial basis.



THE MCELROY, NICHOLSON & MCTIGHE SYSTEM.

There are practically two distinct types of sectional conductor, surface contact system. The first might be classed as magnetic surface contact systems. The general plan adopted in this method is to place underneath the car a magnetic current collecting device, acting upon a magnetic material in the form of an armature or strip located in a closed tube directly underneath the magnet on the car. The movement of the strip, caused by the action of the magnet upon the car, causes the contact rail or conductor, which may or may not be of magnetic material, to be brought into connection with the feeding conductor, thereby supplying current to the motor on the car by means of the collecting device which is in contact with the section under the action of the magnet. The magnet is energized by the current taken from the contact section, which also supplies the motor, and in some methods a small battery is carried which is used to energize the magnet if contact should be lost between the collecting device and the sectional working conductor. As will be readily understood, the magnetic switching devices must be located in the road bed, in close proximity to the magnet under the car, so as to be readily affected by it.

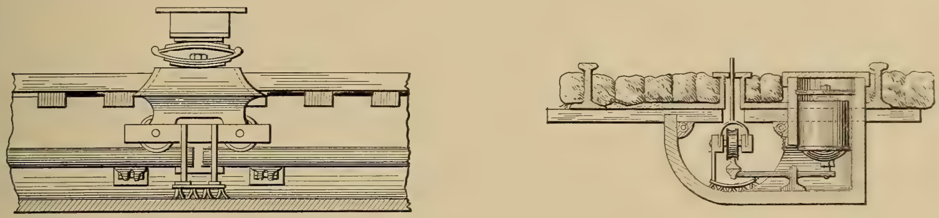


VAN DEPOELE MAGNETIC SURFACE CONTACT SYSTEMS.

The other type may properly be called an electro-magnetic method. Instead of utilizing the direct action of a magnet upon the car to actuate the switching devices, the cutting in and out of the sectional conductor is accomplished by electro-magnets connected

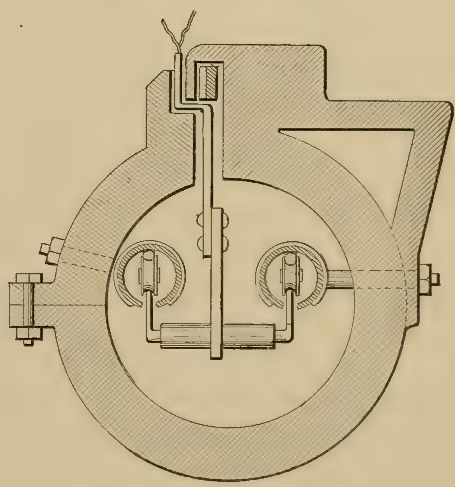
with the different sections and energized by a current from the preceding section. The collecting device on the car generally consists of a long brush, or roller, which also carries the current from one section to another, thereby energizing the electro-magnetic switch and throwing that section into connection with the feeder. The contact conductor may consist of sectional rails or bars on the surface of the road bed, or contact plates located certain distances apart may be used. In either case, however, the contact device must always connect with a new section before leaving the previous one. The electro-magnetic switches are most generally placed in the road bed, but they can also be placed exterior to it and connected with the different sections of working conductor. Various combinations have been made of both the magnetic and electro-magnetic method of operating the sectional surface conductors.

One ot the most prominent of the first type is, no doubt, the Lineff system. An experimental road operated on this system was examined by Mr. Gisbert Kapp several years ago, and described in a paper before the British Association. The operation of this system is very simple. As will be seen from the illustration on this page, the main contact conductor is in the form of an iron T-rail which is placed on top of a trough of insulating material. The rail is laid in short sections, insulated from one another and projecting slightly above the surface of the street. Normally, this sectional rail is not charged, as the supply conductor, which is located in the conduit directly beneath the rail, is not in contact with it. This supply conductor, which is connected with the generating dynamo, is composed of a continuous flat strap of copper, to the lower side of which an iron strap is attached.



THE LAWRENCE SYSTEM.

The magnetic collecting device upon the car is composed of a magnet, set longitudinally, and the rollers at each end are in contact with a section of the contact rail. The rollers form the poles of the magnet and at the same time take current from the rail, although a brush is sometimes used in addition.

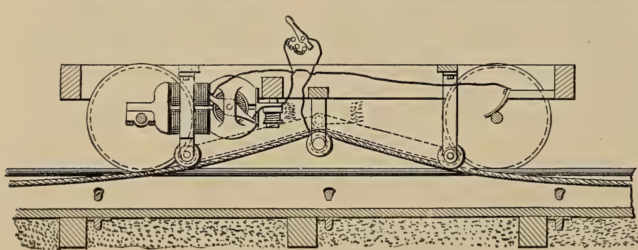


THE CREIGHTON CONDUIT.

When the magnet is energized it will act upon the iron rail in contact with rollers, and the charged strap in the trough will be drawn up against that particular section with which the rollers of the magnet are in contact. In this manner, as the car proceeds, the magnet with its rollers acts upon the rail,

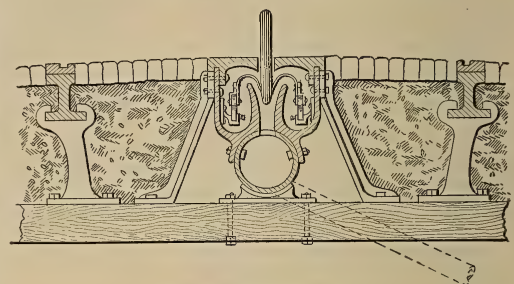
and the supply conductor in the conduit is successively brought into contact with the various rail sections, and is automatically disconnected after the magnetic collecting device has passed and the strap falls from that particular rail section. A battery is carried on the car and is used to energize the magnet if the rollers lose contact at any time with the rail. A system very similar to the Lineff was recently tried at New Haven, Conn. A sectional metallic tube was used, enclosing an iron cable which formed the contact medium.

Another ingenious magnetic surface contact railway is that devised by the late C. J. Van Depoele. In this the magnet on the car acts upon a small carriage traveling in a sealed tube or conduit in the roadbed directly beneath the magnet on the car. The carriage is always in connection with a supply conductor which is also in the conduit. The contact or working conductor is composed of sectional bars or straps of magnetic metal supported upon the conduit so as to be flush with the surface of the street, and insulated from one another. The carriage in the conduit brings these contact sections successively in connection with a supply conductor, as it is caused to move along the conduit under the magnetic action of the magnet on the car. The current is taken from the section by brushes or rollers, which also form the poles of the magnet on the car.



THE FELTROW CONDUIT.

In another method, devised by Messrs. McElroy, Nicholson and McTighe, contact boxes are located at intervals along the road. The tops of these boxes project slightly above the surface of the street and form contact plates. The supply conductor is connected with a pivoted lever in the box, which is normally not in connection with the contact plate on the surface of the street. The action of the magnet causes this lever or armature, which is of magnetic material, to be attracted to the contact plate, and thereby brings it into connection with the supply conductor. The magnet on the car always spans at least two of the contact plates, so that a new plate is brought into connection with a supply conductor before the last one is disconnected.



THE ZELL SYSTEM.

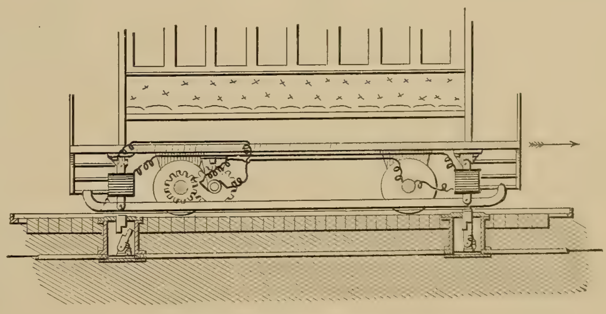
In most of the above and similar systems of electric traction the rails are used as a part of the supply circuit, although two sectional conductors may be used. In nearly all of the various methods that have been devised, a magnet on the car acts on either a band or cable, a movable carriage, or a pivoted lever or plunger which forms the automatic connecting link between the supply conductor and the sectional contact conductor. A method has also been devised in which iron filings act as the connecting medium. Several other methods have also been devised in which the contact and supply conductors are connected by mechanical devices operated by the weight of the car. Such methods, however, appear to be entirely impracticable.

Taking up the second class of surface contact system, we may consider the

method devised by Mr. C. K. Harding as a fair example. The working or contact conductor, which is laid flush with the surface of the street, is supported upon a continuous closed conduit. This conductor is in the form of a metallic bar in short sections, which are insulated from one another, and each of these sections is connected with an electro-magnetic switching device located in the conduit which also supports the contact bar. The car is provided with a suitable current collecting device, either a brush or roller, which rubs on the contact bar. As the car advances and the current collecting device comes in contact with the new section of the imbedded bar, the electro-magnetic switch is actuated by the current from the previous section and switches the new section into connection with the supply conductor which is carried in the conduit, but is insulated, except at the switches or cut-outs. After the car has moved over the section and the current collector is no longer in contact with the bar, the electro-magnetic switch automatically disconnects that section. In this way each successive section of the contact bar is put in and out of connection with the source of current supply, and only those sections in contact with the collector are kept alive or charged. The collecting brush must always make contact with a new section before leaving the last, so that continuity of the current supply is maintained.

Another interesting system of this type is that devised by Messrs. McElroy and Nicholson, which, although upon somewhat different lines, is operated on the same principle. Instead of using a sectional rail, contact plates are located at intervals along the road. These contact plates are supported on suitable boxes imbedded in the road bed and the electro-magnetic switches are placed in these boxes. The current collector on the car consists of a long brush which reaches from one contact plate to another. The electro-magnetic switches are operated, as in the previous method, by the current derived from the preceding contact plate. This system is very much the same as the system devised by the same inventors which has been previously described.

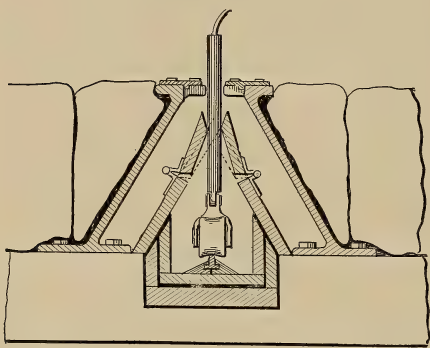
In order to overcome the difficulty experienced in placing the electro-magnetic switches in the roadbed, a method has been devised by Mr. G. T. Woods, in which the cut-outs are located adjacent to the track on suitable supports or in pits. In this plan a number of the switching devices are located together at a central point in the section of road which they control, and each of the electro-magnetic switches is connected with its respective contact plate or section. The writer some time ago experimented with this type of surface contact electric railway. Contact plates were located along the road bed and supported upon a conduit which contained the various wires. The road was divided into sections of several hundred feet, and a wire was connected to each one of the contact plates, which were about 10 feet apart, and was carried through the conduit to a point where the cut-outs controlling that section were located. These cut-outs



THE MCELROY & NICHOLSON SYSTEM

were placed in boxes upon poles located adjacent to the track, and each box or distributing station contained all the switches for controlling that particular section of track. The car was provided with a long metallic brush which made contact with the plates in the road bed. As the brush made con-

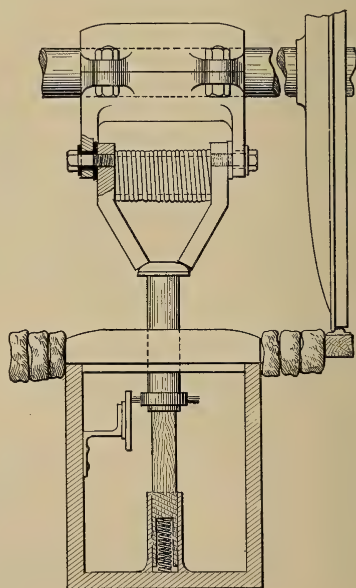
tact with each plate, the electro-magnetic switch located in the distributing box was actuated, and connected that particular plate with the supply conductor, which was also brought to each station or distributing point. After the brush had left the plate, the switch would automatically disconnect it from the supply conductor. A small battery was carried by the car so that, if the brush lost contact, the electro magnetic switch could be actuated by the battery and connection with the supply conductor re-established.



THE BUNCE CONDUIT.

The most recent attempt in this direction has been the trial of the Johnson & Lundell road at New York. This system is very much on the same lines as any of the above. The working conductor consists of a sectional rail, laid between the tracks, and the rail sections are controlled by electro-magnetic switches, located in pits or boxes adjacent to the track. A storage battery is also carried on the car, to be used when the connection between the car and the rail is broken. The experiments with the system are said to have been quite promising. The great difficulty with all these systems is that of leakage between the bare contact sections, on the surface of the street, which form one part of the supply circuit, and the rails which generally form the return circuit. No matter how carefully the road is operated, mud, dirt and slush will collect and bridge across between the two parts of the circuit and cause more or less current to pass. It is true that the bare contact conductor is not continuously charged, but only those sections under the various cars are charged; but it must be remembered that each exposed section means so much leakage of current, and if there are many cars upon the road it seems quite probable that the loss of energy will become quite a large factor. It certainly would seem to be a most difficult matter to keep this leakage within reasonable limits upon an ordinary road and at voltages approximating those used in the trolley method. No doubt, with lower voltages of from, say, 100 to 200 volts, much better results could be obtained.

Aside, however, from the above, the cutting in and out of the various sections brings in an element of complication and uncertainty which ought certainly



HENRY'S SYSTEM.

not exist in the perfected method of electric traction. It would seem that the placing of a large number of cut-outs or switching devices along the road, even though they were placed above the ground, would give rise to much trouble. No matter how perfect they may be, there is a chance—and under the conditions a fairly good

chance—of one or more of them failing to operate properly. Under such conditions the section might be charged even after the car has passed, and the consequences will readily be seen. I do not mean to say that such systems as above described cannot be operated satisfactorily, for I believe that, with much lower voltages than have been used in the past, and a simple and an efficient magnetic or electro-magnetic means of cutting out the section, successful operation can be obtained. An element of uncertainty will, however, always remain in such a system, and it is doubtful whether the cost of such a method on an operative basis would be very much below some form of the open conduit.

We now come to a class of electric railways in which it is attempted to obviate the various difficulties of maintaining a continuous conductor in an open conduit by having only that part of the conductor charged which is in connection with the car. This method is really a combination of the open slot conduit, and the sectional conductor as used in the surface contact methods, and may be divided into two distinct types: (1) Systems in which the sections of the working conductors are cut in and out of connection with the source of supply by means of magnetic or electro-magnetic cut-outs. (2) Those in which the sections are operated by mechanical switches, located in the conduit and operated by devices passing through the slot.

In the first type the general construction and plan of the ordinary conduit and wire is retained. The contact conductor, however, instead of being continuously charged, is divided into sections of suitable length, which are normally out of connection with the source of supply, and connected only when current is being supplied to any particular car, by means of electro-magnetic switches operated in the same manner as in the magnetic or electro-magnetic sectional conductor surface systems. In fact, it consists simply in applying the principle of the sectional surface contact conductor and cut-out devices to an open slot conduit. Any of the various forms of magnetic or electro-magnetic means of switching, as previously described, are applicable here for the same purpose. Instead of having only a very short section of working conductor charged directly beneath the car, we can make the section of working conductor in connection with the source of supply of greater length, as it is insulated and protected and placed out of reach.

In the other method, instead of effecting the automatic connection and disconnection of the working conductor with the source of supply by means of magnetic or electro-magnetic switches, the same result is accomplished by means of mechanical switches, located in the conduit and actuated by suitable devices carried by the moving car and projecting into the conduit. In some cases the switch arm also acts as the working or contact conductor or point and is actuated by the current collecting plow, while in others a sectional conductor is used and the various sections are operated by separate switches, which are mechanically operated by the current collecting plow or other suitable device.

As a recent and ingenious example of a mechanical switch, sectional conduit system, we may take the Lawrence railway, which has been tried at the yards of the Harlan & Hollingsworth Company, at Wilmington, Del. The conductor consists of an inverted, T-shaped girder rail, resting on two balanced arms. These rails are 32 feet long and joined together at their ends by means of pieces of vulcanized hard fibre boards, screwed to the under side, making practically a continuous flexible rail, with an insulating air space between each section. The balanced arms are supported on a spindle and are connected to a rod that enters the switch box. A branch of the feed wire enters the top of the box and makes electrical contact with the rod when the latter is raised by the weight of the trolley at the other end of the arm which supports the contact rail. The current then goes through the arm and rail to the trolley wheels. The collector is a compound

affair, that is, it has two wheels, one placed about six inches forward of the other and electrically connected. This prevents any break in the circuit in going from one section to another, and prevents arching in the boxes.

The conduit proper is made of vitrified clay molded in the form of an elliptic cylinder and cut lengthwise, forming two lengths from each casting. These are placed end to end. The ties are laid directly on them and project over to form a support for the cover, which consists of two iron pieces of L section, one on each side, with a space between to allow the trolley to pass. Then the track is paved with stone and concrete. In a double track the box is placed between the tracks, the one box acting for both tracks; but it is so constructed as to make electrical connection to only one track, unless there is a car upon each track, when it makes electrical connection to both.

A system of somewhat similar type, recently tried at Coney Island, N. Y., is that of Albert Stetson. This has already been described in the March number of this magazine.

Another system, also of some interest, is the Munsie Coles system which was recently tried at New Haven, Conn. In this the switch boxes are located in a slotted conduit of rather small dimensions and are separated from one another by a distance of several feet. The tops of these boxes form the contact conductor and are so arranged that they can be depressed by the current collecting plow projecting through the slot. Normally, these contact plates or caps are disconnected from the supply conductor which enters each one of the switch boxes, but when they are depressed by the collecting plow a connection is formed between the supply conductor and the contact plate or cap, and current is thus transmitted to the motor on the car. The collecting plow is always long enough to reach two of the switch boxes, so that a new cap is connected with a supply conductor before the previous one is disconnected.

Whether or not a sectional conductor conduit has any real advantage over the continuous conductor conduit seems to be rather doubtful. It is true that it is quite difficult to insulate a long, continuous conductor in an open conduit, and that the leakage of current can be reduced if the section of exposed charged conductor be decreased, but it would certainly seem that the additional apparatus necessary would greatly counterbalance the advantage gained. Particularly on roads with many cars at frequent intervals would such subdivision of the contact or working conductor be of least advantage. It would certainly seem that if we build a conduit and insulate the conductor in it, a continuous conductor would work in any locality where a sectional system is operated.

In a method devised by Mr. A. J. Robertson, and also by Mr. H. P. Feltrow, the working conductor is laid on supports in an insulating open slot conduit, and contact is made with the conductor by lifting it over rollers, under and supported from the truck of the car. After the car has passed, the conductor falls through the slot into the conduit and rests upon its supports as before. While this method does not seem to promise any practical results it is interesting to note, as it shows one of the many peculiar means that have been suggested to solve the conduit problem.

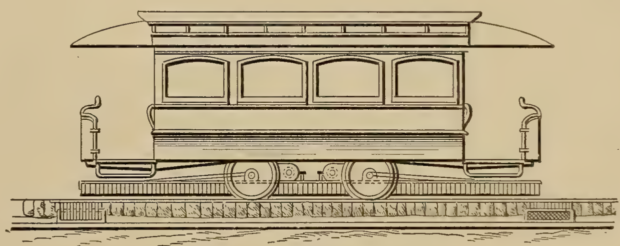
In the various forms of surface contact systems that have been previously described, the contact or working conductor is placed upon the surface of the road bed. In order to obviate the various difficulties inherent in a system in which current is furnished to the car by a bare conductor on the surface of street, several methods have been devised in which the working contacts are raised above the street surface by devices upon the car, and are thereby connected by means of a switch box imbedded in the road bed with the supply wire. The contacts are held up so as to connect with a suitable collecting device on the car, and after the car has passed they fall back into the switch box and are disconnected. Raising these con-

tacts from the switch boxes and above the road surface, may be accomplished by a magnet under the car, which acts upon the contact plate and draws it up into connection with the collecting plow, or by a mechanical device which acts directly on the switch plate or arm.

In a method devised by Mr. J. C. Henry, electro-magnetic means are used to raise the contact plate. A long magnet is carried under the car with its poles longitudinally set close to the road surface. The switch boxes and contacts are located at intervals along the road, and the plunger or rod to which the contact plate or cap is attached projects through the top of the box and is insulated. As the magnet on the car passes over the contact plate, which is of magnetic material, it attracts it and causes the plunger to be drawn up and make contact with the supply wire in the switch box, where it remains until the magnet has passed; then it drops back into the box, out of connection. The poles of the magnet take the current from the contact plates which have been attracted and always attract a new plate before the previous one is dropped.

Mr. Frank Mansfield has devised a raised surface contact system in which a very ingenious mechanism is used to mechanically operate the switches and raise the contacts. The car in this system is equipped with an inclined tongue at each end, which projects downward into a guide slot on the surface of the street, extending the entire length of the road and parallel with the tracks. Adjacent to this guide slot are small switch boxes, placed at regular intervals along the road, and an arm or lever from the switch is so arranged with relation to the guide slot, as to be raised by the tongue which travels in it and brought in contact with a bar upon the car between the tongues at either end. As the arm of the switch box is raised, a contact knob at the end of the lever is automatically switched into connection with the supply conductor which enters the switch box. This contact plate or knob at the end of the switch arm is in connection and rubs upon the bar between the tongues and thereby supplies current to the motor on the car. After the car has passed, the switch arm automatically drops from the hind shoe back into its normal position, and the contact knob at the end of the arm is disconnected from the supply conductor. The switch boxes are made water tight and are so arranged as to be readily accessible. The tracks are used for the return circuit, although two sets of switch boxes may be employed.

Although the raised contact electric railway system possesses several advantages over the ordinary surface contact,



DEWEY'S INDUCTION SYSTEM.

it still retains the objection of having numerous switching devices located in the road bed, and it would seem that with the ordinary wear and tear upon a busy city street, these switching devices would in a very short time fail to work properly. It is doubtful whether the contact plungers would always operate positively, and whether the cost of construction and maintenance would make such a system commercially allowable.

We now come to the class of induction electric railways which would certainly prove a most ideal method if at any time an operative system be produced. In this type all contacts, whether in a conduit, or on, or above the surface of the street, are eliminated. As the name implies, the current is supplied to the car by induction from a series of coils or wires imbedded in the road bed, and which carry an alternating

current of preferably high tension. The current in these coils induces a secondary current in a coil carried by the car and placed in close proximity to the coils in the ground. In fact, the stationary coil in the ground acts as the primary of an ordinary induction coil or converter, while the coil on the car is a movable secondary. Mr. E. Ries, and also Mr. M. Dewey, have devised systems of electric propulsion, by means of electro-magnetic induction, as described.

In the Dewey system the supply circuit consists of a number of coils wound upon U-shaped cores of iron, imbedded at intervals in the road bed. The ends of these iron cores are flush with the street surface. The car carries a secondary coil, wound on a structure similar to that in the street, but long enough to reach two of the primary coils, and inverted so that the ends of the U on the car touch those in the street. The current, passing through the coils in the street, induces a secondary current in the coil on the car, which is used to operate the motors. The voltage of the primary current could be quite high, as the working secondary current could be of any desired pressure according to the winding of the two coils. The great advantage of a system of this type over any of the previous will be seen at once. The fact that there would be no exposed bare wires on any part of the system would make this a most ideal method of electric street railway traction. There are, however, several difficulties which have prevented anything being thus far accomplished in this direction. Primarily among these are, the immense cost of construction, low efficiency, and the fact that the alternating street car motor has not yet been produced.

It is peculiar that with all these various methods of solving the problem nothing really commercially practical has been attained except with the open conduit, and that only in one or two cases. Although, where the open continuous wire conduit is in operation, the conditions are quite favorable, it has really been the only method which has attained any practical success. The other systems that have been devised to meet the requirements of everyday street railway practice seem so far to have been entirely unsuccessful commercially on even the smallest scale. In fact, most of the modifications and elaborations of the continuous wire conduit appear to have more and greater inherent difficulties in the way of general success than exist in the simple open-slot conduit system. The excellent operation of the numerous cable roads, particularly those recently constructed, have certainly shown that an open-slot conduit, if properly built, can be maintained in good condition and drained so as to be practically clear and clean. It remains for the electrician to arrange and locate the wires within such a conduit.

The conduit should be large, well drained, patterned after first-class cable construction, and should be located midway between the tracks, and the top of the slot rail should be slightly above the top of the track. The wire should be located at the very highest possible point in the conduit, protected from exterior interference, and should be supported upon protected insulators in accessible pits or manholes at as great a distance apart as possible. An underbearing contact should be used, and the contact plow should be well protected from moisture and injury, and easily removable. The voltage should be as low as possible. With a good construction and a very low voltage one wire could be used with track return. As the voltage used will greatly affect the cost of construction by increasing the cost of copper for distribution, it must be proportioned so as to be within the allowable first cost.

In conclusion, it may be said that it is a question between the conduit electric railway and the cable road. The trolley will still reign supreme in its own field, but for cities where the overhead trolley is not wanted, the cable is to-day the only system which can be commercially operated to at least partial general satisfaction.

CORROSION OF STEAM DRUMS.*

By James McBride, M. Am. Soc. M. E.

IS there any reason why corrosion should be more active in one place rather than in another, inside a steam drum, properly piped, to connect several boilers in a battery? This subject was suggested by some experiences of the writer, and provoked quite a lively discussion at the Richmond meeting of the Society a few years ago. Specimens of the corroded drums were shown to the members present and examined, and a number of theories were advanced to account for this curious action upon the iron, but no apparently satisfactory cause was assigned. The subject excited such general interest at the time and since, that the writer determined, if possible, to trace the trouble to its true source, and immediately began such experiments, and collected such data as would, in his opinion, lead to this result.

In order that members, who were not present at the Richmond meeting, may have a knowledge of the case the following description of the drums and their attachments will suffice. The drums were made of iron plates ¼ inch thick and single riveted, were 24 inches in diameter and 48 feet long, and were located and piped to the boilers, as shown in the accompanying sketches (Figs. 1 and 2), seven boilers to each drum. They were erected and put to work in March, 1879, and were kept in continuous service, day and night, six days in the week, until the summer of 1890, when, on account of their bad condition, it was found necessary to replace them with new ones, which were made 3 feet in diameter, and of the same length, viz., 48 feet.

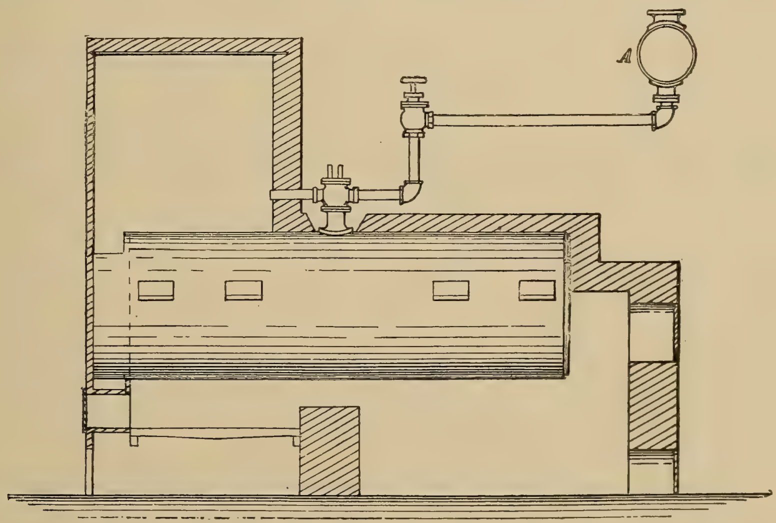


FIG. 1.

During the first few years that the old drums were in use the boilers were not worked very hard; but, as business increased and more steam was required, the boilers were called on to produce more until they were apparently greatly over-

* Presented at the Montreal meeting (June, 1894), of the American Society of Mechanical Engineers.

FIG. 2.

worked. Previous to the increase of work, however, I made a number of calorimeter determinations of the quality of the steam, and the mean for some forty or more tests showed moisture equal to 4⅝ per cent. The demand for more steam continued to increase, and to make matters worse it was decided, in February, 1890, to shut down three boilers at a time for cleaning, stopping one each night and starting one each morning, thus making a continuous cleaning process, so as to avoid the loss of one day each month for cleaning them all at once, as had been the rule. This compelled eighteen boilers to do the work which twenty-one could not do properly.

Early in 1891 it was decided to increase the boiler capacity of the works, which was done by the addition of two vertical boilers of about 130 horse-power each. The two new boilers were put to work on July 1st and were worked in connection with the others, the steam from all leading into one general steam pipe. No calorimeter tests were made from early in 1891 until August, 1891, after starting the new boilers, so that no very definite information is known as to the quality of the steam during the time that eighteen boilers were made to do the work of twenty-one. The amount of evaporation, however, based upon the consumption of feed-water which was metered during a test of 141 hours and which amounted to about 582 cubic feet per hour for the twenty-one boilers and thus giving about 70 horse-power each, does not seem excessive for boilers of this size, 5′ × 15′. (824 square feet.) The new boilers furnish superheated steam at all times, and after this steam mingled with the steam from the other boilers, calorimeter tests showed at times as much as 20 per cent. of priming, although sometimes when the demand for steam was small the tests showed a slight superheat. As a rule, however, the steam was very wet, the mean for six tests taken at intervals from August 7 to August 28, 1891, being 6.82 per cent. of moisture and for eight tests taken from August 29 until September 3, being 10.44 per cent. moisture, the highest at any time being 20 per cent., and the lowest 1.84 per cent., so it is a fair assumption that with 260 horse-power of dry steam from the two vertical boilers mingled with the wet steam from the eighteen horizontal boilers, there was such a large percentage of priming that it must have been very much more, when only eighteen boilers were in service. The particular stress laid upon those calorimeter tests may seem foreign to the matter in hand, but I am firmly con-

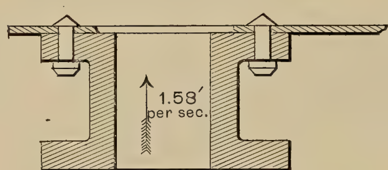


FIG. 3.

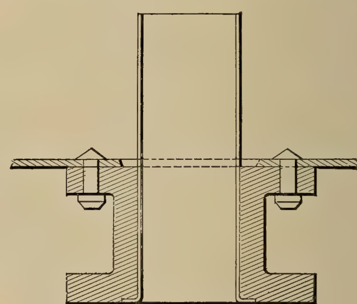


FIG. 4.

vinced that it is the stepping stone to the solution of this problem, and have been thus particular in mentioning them. Having a theory, at the time the new drums were put in as to the cause of the corrosion and the cure for it, I had one of the three new drums piped differently from the others.

It will be noticed from the sketches of the old drums (Figs. 1 and 2) that the 4-inch steam-pipes from the boilers led into the bottom of the drums, no provision being made for the return of the condensed steam and entrained water to get back into the boiler except through the steam-pipes. Two of the new drums were piped similarly to the old ones, and one had the steam-pipes led into the side (Fig. 7), and a drip-pipe from the bottom of the drum led into the boilers below the water-line, thus keeping the drum at all times free from water. All the new drums were kept at work from the summer of 1890 until the 30th of May, 1891, when I had them opened up and made a thorough personal inspection of them. The result of this examination seemed to confirm the opinion which I had formed as to the trouble. The two new drums which were piped similarly to the old ones showed unmistakable evidence of corrosion in the same locations and in the same manner as their predecessors,

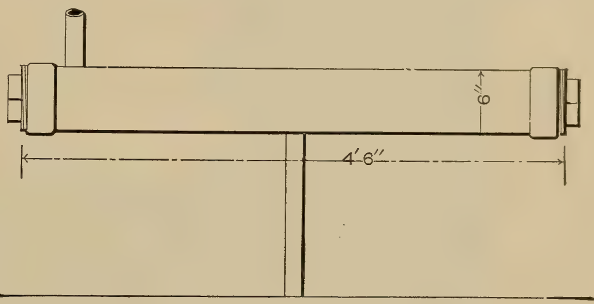


FIG. 5.

while the one piped differently did not show the slightest indications of corrosion in any part.

On August 2, 1891, following, two months later, I examined them again. The corrosion in two of them seemed as active as ever, while the other showed no signs. I now determined to fix one of those which was being corroded, so that it could be kept free from water, similar to the one which was piped on the side. I therefore had 4-inch copper sleeves made and inserted in the nozzles where the pipes entered on the bottom and extending up into the drum about 6 inches, as will be seen in the sketch (Fig. 4). I then put a drip-pipe into each end of the drum and led it back below the water-line of the boiler. This is similar to a method adopted by Mr. Louis G. Engel, of the Brooklyn Sugar Refining Company, who has had some trouble of a like nature with the cast-iron fittings on the pipes leading from his steam drums. These sleeves were put

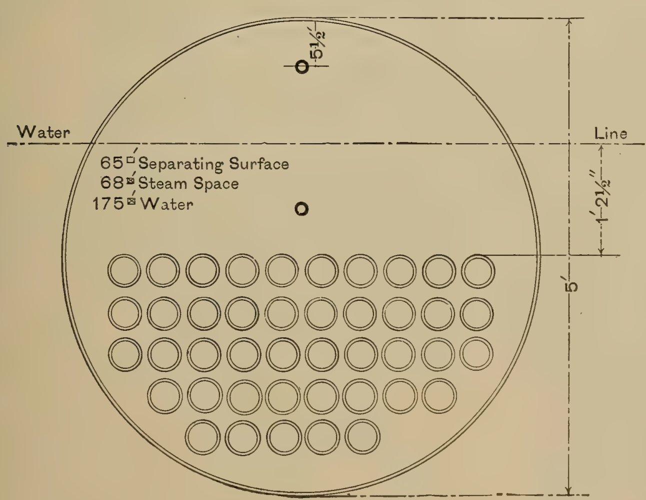


FIG. 6.

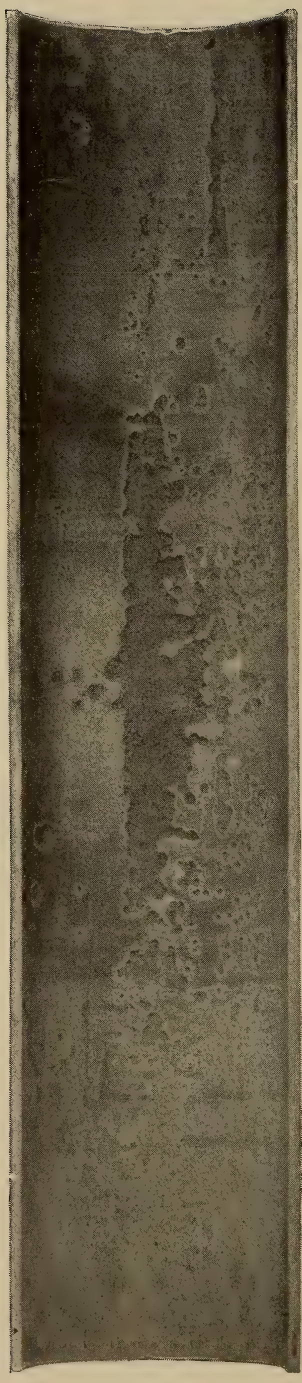


FIG. 8.

in on August 9, 1891, and the drum examined on September 5, following. The appearance of the surface at this time indicated that corrosion was ceasing. The corroded parts seemed to be covered with rust, and there was no place where corrosion appeared to be active.

On November 5, 1891, the factory being shut down for repairs, another examination was carefully made, the result of which confirmed that of August 9. The drum having the sleeves showed that corrosion was ceasing, while the other one piped like it, with the exception of the sleeves, showed that corrosion was still active, but perceptibly less than before the additional boilers were put to work.

Examinations were again made on December 26, 1891, and July 4, 1892. At this latter time corrosion in the drums with the sleeves had entirely ceased. The drum without the sleeves piped on the bottom like the old ones, showed that active corrosion was still going on. New spots had developed and the old ones were getting much worse. One spot on the top of the drum just over the outlet from one of the boilers was particularly bad, and a spot about 3 inches in diameter was being eaten away. All the surface scale of the iron was gone, and there was evidence that this boiler primed badly. The surface looked as though it had been dashed with a mixture of steam and muddy water.

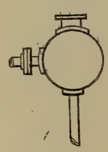


FIG. 7.

On September 5, 1892, another examination was made, the drum without the sleeves showed that the sores and corrosions were growing deeper and beginning to groove at the lower edge, and had the appearance of water having run over them. The drum piped on the side showed no corrosion, but its appearance on the inside showed that the boilers attached to it must have primed very badly, the evidence of this being that there was quite an accumulation of mud near one end which was lower than the other, and on which the drip-pipe had evidently been

closed. A sample of this mud, dried, is shown, and is no doubt the surface scum and sediment which was carried over when the boilers primed. Being firmly convinced that wet steam or priming, or that the water brought out of the boilers into the drum, together with the water of condensation from the surface of the drum, being thrown up and kept in motion in the drum was the cause of the trouble, I decided to tinuously night and day for about nine months. This experimental drum was not covered and had good exposure for surface condensation. There was no drip-pipe and the water had to get out with the steam on its way to the pump. When taken down I had a cross section cut from near the centre and then planed in two longitudinally. Reproductions from photographs taken from these samples are shown in Figs. 8 and

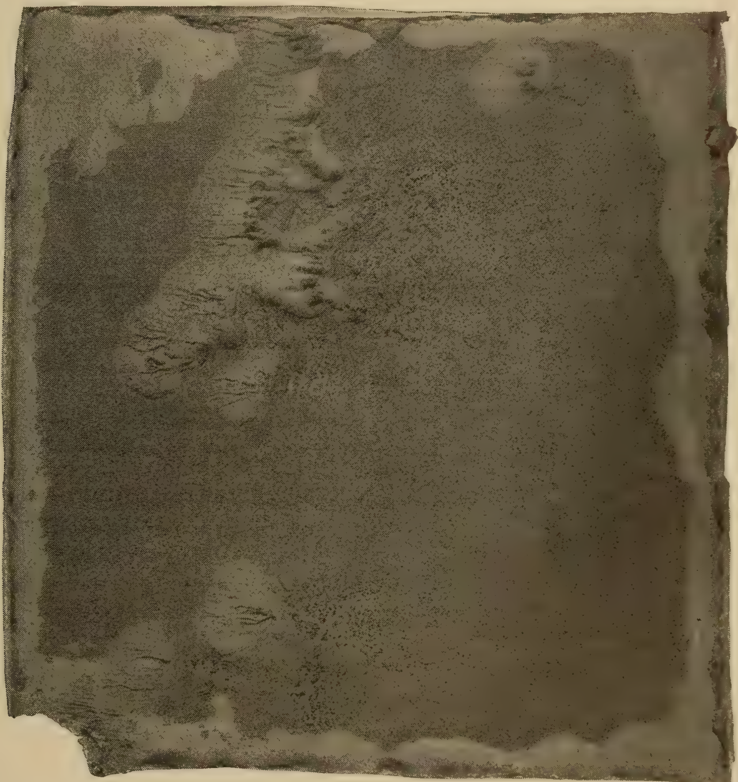


FIG. 9.

make an experimental drum to demonstrate, if possible, if this was true. This drum consisted of a new piece of 6-inch iron pipe, 5 feet 6 inches long, and was located on the top of one of the large drums. (See Fig. 5.) The ends were plugged, and the steam was admitted into the bottom at the centre through a 1½-inch pipe, and taken away from the top at six inches from one end to a feed water pump, and was used con- 9. It will be noticed that on the inside, above where the steam entered this experimental drum, the iron is corroded and eaten in holes, and has every appearance of the corrosive action seen on the large drums.

The water used in the boiler was an exceptionally pure water for boilers, and had mixed with it a large percentage of water of condensation from the copper coils of the vacuum pans. The

water was analyzed and nothing injurious to iron was found in it. The fact that the boilers primed so badly was due, probably, to the fact that the water was carried very high in them (as will be seen from the sketch, Fig. 6), and the pressure was very fluctuating, ranging from 40 to 80 pounds at short intervals. The demand for steam was also very irregular, large demands being made on the boilers at times when the pressure was low, and those who have had experience with vacuum pans know that their capacity for steam is like that of a young pigeon for food ; they never get enough. A pan with 300 square feet of coil surface will make away with 345 horse-power and then call for more.

These investigations have convinced me that the method of piping boilers with the end of the steam pipe lowest at the end next the boiler, so as to allow the water of condensation to run back to the boiler is a fallacy, and in my opinion not a drop of water, while the boilers are steaming, ever gets back to the boiler by this route, even if the pipes were vertical. The velocity of the steam in steam pipes of ordinary size is sufficient to carry along with it any water which may be on the surface of the pipes, so that in the case of these drums piped on the bottom, all the water in them had to go out with the steam, and had to go out as water too, for it could not be re-evaporated. Estimating an evaporation of only 2000 pounds of water per hour for one of these boilers, I figure the velocity of steam through a 4-inch opening equal to about 1.58 feet per second. No water could ever pass down through this opening to the boiler, as it would have to start practically from a state of rest at the edge of the opening (see sketch Fig. 4), and the difference in its specific gravity from that of the steam would not be sufficient to overcome the velocity of the latter. I believe that all drums receiving steam in the bottom should be furnished with sleeves extending up some distance into the drum and the water taken away with drip-pipes, and that all steam pipes should be drained away from the boilers and the water trapped out before reaching the engine.

The conclusions which I draw from these observations and experiments, which have extended over a period of nearly four years, and have been carefully made, are : First. That the corrosion is due primarily to excessive moisture in the steam in the drum. Second. That moisture in this case was due to the priming of the boilers and surface condensation in the drum. Third. That the trouble was aggravated because no provision was made to take away the water from the drums by drip-pipes.

What peculiar action takes place to corrode the iron, under the above conditions, I am unable to say, and whether it is mechanical, chemical, electrical, or a combination of any, or all of those actions, is open to discussion.

JAMES PRESCOTT JOULE.

By Lord Kelvin.

THE unveiling, last December, of a statue of Dr. James Prescott Joule, at Manchester, England, has given that city the possession of a work of art which will ever remain an ornament and an honor to it.

Joule's work began in Manchester, was carried on in Manchester, and finished in Manchester. It began very early, when he was only nineteen years of age. He was not altogether a self-taught man in science. After a good ordinary school education, he had the inestimable benefit of the personal teaching of Dalton in chemistry. He and his elder brother Benjamin were favorite pupils of Dalton. They went to his house in the rooms of the Literary and Philosophical Society of Manchester for regular daily lessons, and were a little disappointed at first when they found that Dalton, instead of introducing them straight away to the grandeur of the atomic theory of chemistry, kept them to the grindstone, forced them to do their additions correctly, and held up to them, as something essentially necessary for them to learn, the practice of trigonometry and the logarithmic tables. James Joule and his brother got great good from that early severe, almost hard, training by Dalton. They were both full of original brightness and acuteness in their observations. They went through the country, even before they came to be pupils of Dalton, making memoranda of what they saw and heard, an aurora borealis or a wonderful thunderstorm, or sounds of artillery or lightning, they could not tell which. Some of their journals they afterward showed to Dalton, who thought so well of their descriptions that in one instance he was able to say to them, "Those sounds you heard were not human artillery but they were the thunder of an outburst of lightning at sea forty miles south of Holyhead."

The two brothers continued pupils of Dalton until the failure of his health; but for a year after that, and no doubt to the very end, they continued to receive ideas from that great man. It must not be thought that Dalton only taught them arithmetic and trigonometry. I rather emphasize that point with an eye perhaps to the young men who aspire to follow in Joule's footsteps, and upon whom I wish to impress the conviction that it was hard work, early begun and persevered in and conscientiously carried out. That is the foundation of all great works, whether in literature, philosophy or science, or in doing good to the world in any possible way. In electricity and electro-magnetism Joule, I think I may say, was wholly self-taught. All he knew he learned from his own reading—from reading in text books and in Sturgeon's Annals of Electricity, and also from conferences with Sturgeon himself. The Literary and Philosophical Society of Manchester has the distinguished honor of having been the cradle of Joule's scientific childhood when it was Dalton's home, and of being afterward Joule's life-long scientific harbor. From those early days he kept constantly in touch with that society. Many of his most important papers were first given to the world there, and during the last years of his life he was an exceedingly regular, it might almost be said a constant, attendant at the meetings of the Society. An interesting and sympathetic memoir of Joule, with much important scientific information and judgment regarding his work, by Professor Osborne Reynolds,

constitutes the sixth volume of the fourth series of its "Memoirs and Proceedings."

A great surprise that came out very early in Joule's work was burning without heat—an absolutely novel idea which Joule developed most wonderfully and most magnificently by his experiments on the generation of heat in the voltaic battery. Joule was the first to develop the idea, and it came to him not as a bright flash of genius, but as the demonstrated result of years of hard, measuring, calculating work. This burning without heat was a fundamental idea that pervaded all Joule's work. A few year's later he expanded it in an admirable way. About 1844, in a joint paper by himself and Scoresby, "On the Mechanical Powers of Electro-magnetism, Steam and Horses," he brought out the startling but truly philosophical idea that when a man or any other animal walked uphill, only a part of the heat of combustion of his food was developed, and that it was only when the body was quiescent, or walking about on a level, or going downhill that the chemical attraction between the food and the oxygen dissolved in the blood developed its whole energy in animal heat. He showed, further, that a horse or a man employed in doing mechanical work against resistance was more economical of fuel than was any steam engine hitherto realized. This was a very far-reaching idea, and seemed to hold out prospects of greatly advancing the efficiency of the steam engine. That promise has not been lost.

It is due to Joule more than to any other individual that the great improvement of surface condensation is now universal, although it was very rarely practiced before 1860 or 1862. Between 1855 and 1862, Joule and I had a small steam engine fitted up in the stable of his father's house, Oakfield, for use in our joint investigations on the thermic effects on fluids in motion. To that little steam engine Joule applied a surface condenser on an entirely new principle and plan, which gave us such good results that, starting from it, he undertook a special investigation on the surface-condensation of steam with the assistance of a grant from the Royal Society for the purpose. The results of this very elaborate investigation, communicated to the Royal Society on December 13, 1860, and published in The Philosophical Transactions, have proved to be of enormous practical importance. They led directly and speedily to the present practical method of surface-condensation, which is one of the most valuable improvements of the steam engine, especially for marine use, since the time of Watt.

But I have not yet touched upon Joule's great fundamental discovery, the discovery which is first in every one's mouth when asked what was Joule's work?—The Mechanical Equivalent of Heat. It was not merely by a chance piece of experiment or of guessing that he stumbled on a result which was afterwards found to be of great value. It was measurement, rigorous experiment and observation, and philosophic thought all round the field of physical science that made the discovery possible to him. Very early, however, in his working time Joule brought out the mechanical equivalent of heat, and in a paper at the British Association at Cork, in 1843, published afterwards in The Philosophical Magazine, he gave the number "770." Six years later a second determination gave him a result about ⅓ per cent. larger, and twenty-nine years later he completed a third determination. The result of this final investigation of Joule's is 772.43 Manchester foot-pounds for the quantity of heat required to warm from 60° to 61° Fahrenheit, one pound of water weighed in vacuum, which is about $\frac{1}{20}$ per cent. greater than the result of 1849 expressed in the same term.

In the year 1824 a great theory was originated by a very young man, who died only a few years later—Sadi Carnot, son of the Republican War Minister and uncle of the late president of the French Republic. It was he who made "Carnot's theory" a household word throughout the world of science. Carnot's theory gave an important funda-

mental principle regarding the development of motive power from heat. Joule's work, on the other hand, so far as the mechanical equivalent was concerned, was the generation of heat by mechanical work. It was quite the middle of the century before Carnot's theory began to attract attention; but Joule was early made acquainted with it, and after fighting a little against it, as differing from his own theory, he, of all others, took it up in the most hearty manner. I can never forget the British Association at Oxford in the year 1847, when in one of the sections I heard a paper read by a very unassuming young man who betrayed no consciousness in his manner that he had a great idea to unfold. I was tremendously struck with the paper. I at first thought that it could not be true, because it was different from Carnot's theory, and immediately after the reading of the paper I had a few words of conversation with the author, James Joule, which was the beginning of our forty years' acquaintance and friendship. On the evening of the same day that very valuable institution of the British Association, its conversazione, gave us opportunity for a good hour's talk and discussion over all that either of us knew of thermodynamics. I gained ideas which had never entered my mind before, and I thought I too suggested something worthy of Joule's consideration when I told him of Carnot's theory.

Then and there in the Radcliffe Library, Oxford, we parted, both of us, I am sure, feeling that we had much more to say to one another and much matter for reflection in what we had talked over that evening. But what was my surprise a fortnight later when, walking down the valley of Chamounix, I saw in the distance a young man walking up the road towards me and carrying in his hand something which looked like a stick, but which he was using neither as an Alpenstock nor as a walking stick. It was Joule with a long thermometer in his hand, which he would not trust by itself in the *char-à-banc* coming slowly up the hill behind him lest it should get broken. But there comfortably and safely seated on the *char-à-banc* was his bride—the sympathetic companion and sharer in his work of after years. He had not told me in Section A or in the Radcliffe Library that he was going to be married in three days, but now in the valley of Chamounix, he introduced me to his young wife. We appointed to meet again a fortnight later at Martigny to make experiments on the heat of a waterfall (Sallanches) with that thermometer; and afterwards we met again and again and again, and from that time, indeed, remained close friends till the end of Joule's life. I had the great pleasure and satisfaction for many years, beginning just forty years ago, of making experiments along with Joule, which led to some important results in respect to the theory of thermodynamics. This is one of the most valuable recollections of my life, and is, indeed, as valuable a recollection as I can conceive in the possession of any man interested in science. Joule's initial work was the very foundation of our knowledge of the steam engine and steam power. Taken along with Carnot's theory it has given the scientific foundation on which all the great improvements since the year 1850 have been worked out, not in a haphazard way but on a careful philosophical basis. James Watt had anticipated to some degree in his compound engine and his expansive system the benefits now realized, but he was before his time in that respect and he had not the complete foundation which Joule's mechanical equivalent and Carnot's theory have since given for the improvement of the steam engine.

ON SKIDWAYS READY FOR LOADING.

IN WHITE PINE FORESTS.

By B. W. Davis.

IT has been truly said, that "one half of the world does not know how the other half lives." The writer does not intend the quotation as a text, but it suggested the thought that it might be of interest to the readers of CASSIER'S MAGAZINE to go with him on a trip through the white pine forests of Northern Wisconsin.

The proper time of the year for beginning such a trip is in brown October. Let us say, therefore, that the first day out on our long winter's tramp is October 25, as it is about this date that the "shanty-boss" picks out a few good "swampers," sees the logging kit loaded on the cars that are to haul the outfit to the nearest point on the railroad where the winter's work is to be done; and as all the food for man and beast must come to this point, the boss and his crew build a "tote station," or warehouse, in which will be a bunk or two for use of the teamster and those going to and from camp. The distance from this station to camp may be anywhere from one to fifteen miles.

A good camp for the accommodation of a crew of seventy-five men will consist of a sleeping shanty, or men's quarters, stable, blacksmith shop, cook shanty and store house, all of which are built of logs in a more or less tasty manner, according to the ideas of boss and cook, for these two men are the "high and mighties" in a logger's crew. Those who visited the World's Fair last summer had the pleasure of inspecting a model camp and a prize load of logs. The load of logs was the genuine thing, and was actually loaded and hauled the winter previous. The cabin, however, had more of the artistic make-up than is usual, but every saw mill man or logger who visited that spot in his miniature trip around the world took a deep, long breath and said, "Well, this looks like home."

We will jump ahead a few weeks and consider that all things are moving in

their appointed way, that our party dropped off the train at the "tote station," yesterday, and after helping the teamster load up about 4000 pounds of "grub," consisting of baled hay, oats in sacks, quarters of beef, flour, rice, beans, baking powder, tea, coffee, salt, smoking tobacco and plug, we turn in for the night and dispute possession for the extra bunk with the teamster's dog, finally give up the unequal fight, and allow him to turn in with us. About 4 A. M. we are called out to eat breakfast by the light of a tubular lantern, the team is hitched up, and we are off for camp, arriving there at any time from noon to midnight — depending on the distance.

You are up betimes next morning, and at once begin picking up the threads that lead you to a full understanding of life in a logging camp. The division of the crew is something puzzling to the tenderfoot, as the names used are purely technical and unlike anything you may have met before, with the exception, possibly, of the horse teamster, ox teamster, shanty boss, cook, cookee, blacksmith and scaler. The rest of the crew are swampers, loaders, sawyers (top and under), loading men, skidders, cross-haul teamsters, peavy, cant-hook men and the ice road crew. The swampers take the log from where it fell to the skidways; loaders, as their name indicates, load the logs from the skidway on the sleds; sawyers cut the trees down (the ax is no longer used except to trim branches, etc.) and cross-cut the tree into logs; the top-sawyer, so-called, as he takes care of the saw, keeps it in order and bosses the under-sawyer; landing men are at the river end of the logging road, unload the sleds, put logs in even tiers called rollways, and place them in such manner as will allow the spring rise in the river to float them off without a jam; skidders roll the logs up in banks alongside the logging road, and are aided in this work by the cross-haul teamster and his ox or horse team; peavy and cant-hook men are so called from the expert manner in which they handle these very unwieldy and odd-looking tools.

The ice road makers are somewhat of a novelty, as they are a product of later years, and are the result of man's ingenuity to overcome Nature's uncertain time-card in the matter of snow storms: sometimes there is too much snow, and, then again, there are winters with little or none, all of which keeps the loggers in a state of uncertainty, to overcome which some bright fellow,—his name is lost to history,—concluded to use Jack Frost, a water barrel on runners with a stove under it, a four-horse team and a tool called a marker or rut cutter. The operation of ice road making is simple, and is used only on the main logging road from skidway to landing. The first move is to go over the road with a snow plow, making a wide level track, after which the tank on runners is filled with water, the stove under it being kept supplied with dry wood fuel to prevent

A LOGGING CAMP.

A BIRD'S EYE VIEW OF A SAW MILL, MILL BOOMS AND DOCKS.

the water from freezing. During all this time that we have been looking over the works the mercury has been "climbing" down cellar, until it marks forty-five degrees below zero. The tank has two spouts just over and at the back end of the hind bobs, the entire rig being something like a street sprinkler, except that the water runs out in two solid streams, and the tank is of square section and long, to fit a "bob sled." The rut cutter is attached to the back end of the runner, cutting a groove in the snow and dirt of the road; the water falls into the rut thus cut, and Jack Frost does the rest in very short order. The shape of the groove is the reverse of the sled shoes, the runner being convex and the groove concave. By this method it will be readily seen that we have produced a grooved ice railroad in which the logging sleds slip along with very little effort on the part of the horses. As a rule, the logging roads are built beside a brook bottom which flows toward the river, and as a result the loaded sleds are hauled down grade and the empty sleds up grade, making it easy work for the team.

About the last of March finds the woods work completed, the last load on its way to the landing, and all hands anxious to start for home. At the saw mill office the time checks are exchanged for bank checks, and from then until time for the "drive" "Rome howls," for the boys have been working hard all winter, miles from anywhere, and this is their first chance to do a little artistic decorating with red paint.

The next thing down on the programme is to decide who will "drive" the smaller lakes and streams and who will "drive" the main river. After these few men have been selected by the log owners the boys are keen to be engaged on this or that drive. The work is extra hazardous and very disagreeable, as there is danger all the time, and every man will be wet to the skin from head to foot almost the entire time of his engagement. To ride a log in its mad rush down river, in company with thousands of its kind disputing the

right of way with miles of ice, rocks and drifting snags, is not child's play, and takes a cool head, a steady hand and the nerve of a dare-devil; a slip of the foot means a plunge-bath in ice-cold water, and possibly death from log jams or being unable to come to the top. The unfortunate who goes in must find a place to come out, with small chance of any help from others on the drive, as his plunge may not have been noticed, or the rest of the crew may be too far away to offer help of any kind.

The last few years have seen many changes in the manner of putting in and taking care of a log crop. The description just given is the usual plan of campaign for the river mills, but a new class of saw mills has come to the front under the general name of "railroad mills." As most of our illustrations are taken from such a plant, it may be well to give a short sketch of just how the "invaders" work. The reason for such an outfit as we are about to describe is the fact that the pine is so situated that river driving is out of the question. The company builds a railroad of its own, running from some well-located point on a trunk line back into the timber. This railroad takes the place of lake and stream, giving the company the privilege of logging the year round, as the logs can be hauled to the mill at any time. Another point very much in favor of such a plant is the fact that every log cut comes in, while with the older method many of the logs never reach the mill boom, but are "hung up" by high water or become water-soaked and sink, in which case they are termed "deadheads."

The writer has in mind one large white pine log which scaled over 1000 feet, and was called the "king log" of the camp's cut. This particular log was the means of killing one of the landing men and from that moment was known as "Charley's Ghost," and not a man would touch it during the

TAKING LOGS INTO A MILL BY AN ENDLESS SPROCKET CHAIN.

LUMBER READY FOR SHIPMENT.

drive that year or any succeeding year, and as a result of such neglect "Charley's Ghost" did not come to the boom for five years, which shows how efficient and necessary the drivers are; but, as Kipling says, that's another story. To return to our railroad plant, the woods work, loading, etc., is carried on in the same manner as for the river mill, except that the railroad takes the log in the woods at the skidway and soon drops it in the mill pond. It is rather a difficult matter to furnish a mill with logs from the dry ground, and for that reason all of the logs are dumped into a pond and then they are easily handled and driven to the pull slide and chain, which hauls them up to the log deck on the saw floor of the mill. At this point the log loses its identity and is quickly converted into all shapes and sizes of timber, joist, boards, strips, lath and shingles.

FILING ROOM IN A SAW MILL.

There is one other point which should be mentioned in order to make clear our illustrations—that of running the mill all winter. This is done by making a large coffer dam in the mill pond and condensing all the ex-

THE WARM WATER POND FOR THAWING OUT FROZEN LOGS.

BAND SAWING.

haust steam by running it into this coffer dam, which encloses about three-quarters of an acre. This keeps the pond open and thaws the frost out of the logs. A frozen log is a very hard thing to saw. In order to soften the log as much as possible, a huge steam-box is constructed with sliding doors at each end. This is filled with logs, live steam is then turned on and the temperature is run up to about 150 degrees, which makes the log as tender as a spring chicken, and while it is true that Jack Frost has one more chance at our white pine friend before reaching the saw, the time is so short that he does no harm.

One more point and my story is done. We, of the North woods, are a long way from home; we live in a wild country and the business is full of danger, but at every logger's shanty and every saw mill town the latch-string is always out to those who wish to pay us a visit, and will put up with what, at first, looks like poor accommodation and coarse food; but if you will spend a winter with us, you will find that after tramping the woods all day, with the mercury 40 degrees below zero, well-cooked pork and beans and buckwheat cakes with genuine maple syrup make a supper fit for the gods; and when you turn into your rude bunk at night, with balsam boughs and silver-gray blankets as sleep inducers, you will be surprised when the cook's call for breakfast startles you, for you say to yourself, "I only this moment turned in." But as you look at your watch and find that you have been sleeping eight full hours, the thought comes to you that all the good things in life are not found in the big cities.

LOADING A LUMBER SCHOONER.

AERONAUTIC ENGINEERING MATERIALS.

By R. H. Thurston.

THE most urgent demand for strong materials of construction comes from the designers and builders of machinery which must be transported, and especially when it must take part in its own transportation—as in the case of the locomotive and the marine engine—while the lack of still stronger materials than those we now are able to produce is one of the greatest difficulties to-day obstructing the engineer and the mechanic in the endeavor to enter upon a new and most attractive field—that of aeronautics.

Treating ot the subject in a paper presented at Chicago last year before the International Engineering Congress, the author maintained that, no matter how ingenious the inventor or skillful the maker, progress in aviation is impossible until propelling machinery can be produced powerful enough to lift and impel itself and its enclosing air-ship ; or, otherwise and perhaps better stated, until such machinery can be built light enough to sustain itself with its load, with a large reserve of lifting and impelling power.

The express locomotive weighs 100 or 150 pounds per horse-power, and takes several times its weight along the rail at from 50 to 80 miles per hour ; the marine engine, occupying one-fifth the space of the containing vessel, weighs from 500 and 600 down to 200 and 300 pounds per horse-power ; while torpedo-boat, and fast yacht machinery weighs in many cases as little as 100 pounds per horse-power ; but these are all vastly higher than the maximum weight permitted by the aeronaut. The birds weigh certainly no more than 20 or 25 pounds per horse-power, and man must rival and surpass them. Machinery weighing 25 pounds per horse-power is probably the practical limit.

A good draft-horse weighs about 1500 to 2000 pounds per horse-power. Strong men work at about the rate of 1 horse-power per 750 pounds weight as a minimum and not far from double that figure as a maximum. The animal's muscular substance is subjected to a maximum stress of not more than about 100 pounds per square inch, in ordinary work 15 or 20. Mullenhoff reports the stress per unit section of a bird's muscles as about ½ to ¼ kilogram per square centimeter, or not far from 15 to 20 pounds per square inch. Pénard, on the other hand, gives the resistance of a feather as about 45,500 pounds per square inch, about the strength of the softer grades of bar and sheet iron. But its density is about ⅓ ; thus making its value for aeronautic purposes very great, giving 6 times the carrying power per unit weight. By comparing these figures with those given by the authorities for the actual stresses on the muscular fibre, the animal machine would seem to have a very high factor of safety.

It is most wonderful that, with these low stresses, with high factors of safety, and with comparatively bulky and weighty fuel, these animal machines should be able to lift into the air a load equal to 50 per cent. of their own weight, and, unloaded, to traverse a thousand miles without stop in a day. It seems very probable that a weight of somewhere about 10 to 12 pounds per

horse-power for the machinery of propulsion must be worked for if success is to be either certain or satisfactory in this particular detail of the problem which the aeronaut seeks to solve as a would-be aviator. This reduction of weight may be accomplished by advances in either or all of three directions: (1) Reduction of weight of material by improved design and proportions; (2) increase of ratio of strength of the materials used to their density; (3) increased velocity of motion of the moving parts of the machinery transmitting energy.

By careful selection and ingenious combination of the lightest and strongest available materials, Stringfellow, Henson and Hargreaves have produced machinery of the minimum weight, and the prize engine of the British Aeronautical Society weighed but 16 pounds per horse-power; that of Maxim, built of tempered tool steel, weighs, with its boiler, less than 10 pounds per horse-power; and the engines of Langley, without boilers, are similarly reduced in weight to 6 pounds per horse-power.

Of the two factors which produce the resultant energy in any case of application of power to useful purposes, force and velocity of motion of the point of application of the force, that which is most desirable from the stand-point of the engineer is velocity, since an increase in velocity affects weight, strength and cost of construction comparatively little. The first necessity therefore is to secure such a design as will give the largest practicable value to the velocity. When this is done there remains the possibility of reducing the ratio of weight of machine to power developed by reduction of the weight of each element of the machine to the smallest quantity capable of sustaining the effort transmitted by it; reducing the ratio of density of material to strength while, it must be remembered, retaining also so much of ductility as is required to insure safety through that resilience which must be present to meet the action of blows and shocks. It is not enough that the material chosen is strong nor is it sufficient that it shall be light.

Steel is three times as heavy as aluminum, but it may be given from four to five times its strength, and is much the better material, so far as we can now see, for aerial constructions. The metal weighing 480 pounds per cubic foot will sustain, in its strongest form, perhaps 100,000 feet of its own substance; while the metal weighing but 160 pounds per foot can uphold only about 25,000 feet in the form of a suspended bar, or about 60,000 feet in fine wire. This last is the true gauge of the constructive value of the metal, as of any other substance to be used as a tie. The height of the column which will stand without crushing or bending is the similar gauge of the value of the substance in compression and the span of a standard form of girder which would just sustain itself—that for transverse loading. The following figures permit this sort of comparison to be made among the various familiar metals of common use in machine construction, as given by Messrs. Hunt, Langley and Hall:—

Density and Weight of Metals.

Metal.	Weight of 1 cubic foot.	Tensile strength per square inch.	Length of a bar that just supported its own weight.
Cast-iron	444 pounds.	16,500 pounds.	5,351 feet.
Ordinary bronze	525 "	36,000 "	9,874 "
Wrought-iron	480 "	50,000 "	15,000 "
Hard struck steel	490 "	78,000 "	22,922 "
Aluminum	168 "	26,000 "	22,285 "

It is seen that the value of aluminum for purposes demanding maximum strength per unit of weight is substantially the same as that of steel having a tenacity of between 75,000 and 80,000 pounds per square inch, while both metals are superior to the others in the

list and 60 per cent. better than wrought-iron, the next best in the catalogue.

The limiting value of the materials of aeronautic construction may be assigned by reference to the fact that thus far only the fine steels have been considered sufficiently strong and light to permit the construction of machinery for such purposes. Their cost, when thus employed for all the working parts, and in forms giving maximum strength with minimum weight, is very great; but this is a comparatively unimportant matter for present purposes. Such steels are capable of sustaining their own substance in lengths of from 25,000 to 100,000 feet, and we way take the former figure as our limiting value. Any material incapable of sustaining 25,000 feet or about five miles of its own substance in a pendent bar may be ruled out of the list of those which promise to be of special service in future aeronautic construction. Similarly, any substance thus incapable of sustaining about 15,000 feet, or about three miles, without exceeding the elastic limit of the material at the point of suspension, may be also discarded from the list. Still another gauge of the value of the material is the quotient of its tenacity by its density. If the tenacity in pounds on the square inch, divided by the weight in pounds per cubic foot, is less than about $\frac{t}{w} = 150$, it is not wanted; or if the quotient, elastic resistance divided by weight is less than $\frac{e}{w} = 100$, it will not suit such purposes. The limiting value is, in fact, in most cases, if not in all, the elastic limit of the material. The elastic limit of the substance never has the same relation to the ultimate strength in any two materials. In the softer metals, as in copper, tin, lead, zinc, there is no definite elastic limit until one has been produced by load, the metal stretching sensibly with every sensible load, however small. Iron and steel have a definite elastic limit at their first loading; but it rises with every load in excess of the primitive elastic limit, until finally the elastic limit coincides with the ultimate resistance, and the piece then breaks without the occurrence of extension marking the separation of the two critical points, now united.

Fiber and other organic substances promise great usefulness in the construction of some form of aeronautic apparatus, and have in fact, in ballooning, been the only forms of material meeting the requirements of that branch of engineering work. Of the available forms of fibre, silk, hemp and glass, with perhaps in some cases, cotton, are the kinds employed. Hemp, iron, and steel rope weigh respectively, according to Clark, 3, 2 and 1½ pounds per fathom, for a breaking load of about 6000 pounds. Their breaking lengths are, on this rating, 12,000, 18,000 and 24,000 feet, and they will sustain, without exceeding their working loads, 2000, 3000 and 4000 feet respectively. On this rating, hemp would not answer our purpose. Braided linen, "silkworm gut" or "sinew," and "catgut" are some of the strongest fibres. They have about the value of steel at a tenacity of 115,000 to 125,000 pounds per square inch and less than one-half that strength which is attainable in the latter, in sections similar to those of these natural fibres. We find nothing in nature that can compete for present purposes with the finest steels in the form of the finest wire and thinnest ribbon or sheet. No natural substance can be found as yet which can approach the rival metals in hardness and safety against injury by shock or abrasion, both of which qualities are of great importance. The fabrics woven of the above mentioned fibres have substantially the same rating as the fibre of which they are composed. But these fabrics may sometimes have peculiar value for special purposes, such as for the covering of balloons and the construction of aeroplanes, and may prove more useful than the otherwise superior metals.

The woods, combining, as they do, lightness, stiffness, and considerable strength, are often found the very best of all the materials of construction where this combination of qualities is

important. Some of the most successful of all attempts to construct aeronautic apparatus have been the result of skillful application of the strong, stiff and light woods in their production. Bamboo, ash, spruce, and the pines most free from pitch, have been especially suitable. Several tables are available showing the coefficient of tensile and compressive resistance of the woods common in our markets. The densities, and weights per cubic foot of the woods vary from 0.5 to 1.2, and from 30 to 70 pounds respectively, according as they are light and well seasoned on the one hand, and heavy and green on the other. For aeronautical purposes all timber should have been at least a year seasoning and should be so treated when in the structure that it cannot absorb moisture. The weights per cubic foot and the densities of seasoned woods of most promise for light and strong constructions are the following :

the Ordnance Bureau of the United States War Department to have a tenacity of not less than 65,000 pounds per square inch, with a ductility not less than 20 per cent., and not less than 55,000 pounds tenacity ; and 15 per cent. elongation in test pieces four diameters long condemns the metal. Castings weighing three or four tons have been made to these specifications and given tenacities exceeding 70,000 pounds, and elastic limit of above 30,000 pounds, with elongations exceeding 33 per cent. and a contraction in area of above 45 per cent. Such metals, especially in castings of parts often difficult to otherwise form, give promise of becoming enormously valuable in locomotive, marine engine, and aeronautic work. Comparing them with sound aluminium, we find that they may be made to sustain a length of about 25,000 feet, have a ratio of tenacity to heaviness of about 140, and if, as is

Material.	Specific Gravity.	Weight per cubic feet.	Material.	Specific Gravity.	Weight per cubic feet.
Ash	.69	43	Mahogany—Spanish	.72	45
Beech	.66	43	Oak—White	.76	43
Birch	.57	35	Oak—Live	1.07	67
Cedar	.56	35	Pine—White	.42	29
Elm	.57	36	Pine—Yellow	.54	34
Fir (Norway Spruce)	.51	32	Spruce	.50	31
Hemlock	.37	23	Sycamore	.62	39
Hickory	.69	43	Walnut—Hickory	.67	42
Lancewood	.72	45	Willow	.49	37
Mahogany—Honduras	.56	35	Yew	.80	50

A study of figures bearing on the subject shows that the woods of a better class generally may be taken as equivalent to the steels of the strongest classes for such purposes as the former best suit. It is evident from a survey of the more familiar metals that lead, tin, zinc and copper are too weak in proportion to their weight, to serve as materials of aeronautical construction except under such circumstances as to compel their use in spite of their unsatisfactory tenacity.

Steel castings seem likely to prove peculiarly valuable for use in the framework and massive parts of machinery in which lightness is important. Those made for use in ordnance construction, as for gun carriages, are expected by

perfectly practicable, given somewhat greater hardness and strength for aeronautic than for other construction, and especially as they will usually be employed in small parts or in parts having small sections, they may, by Whitworth's or other method of solidification, be made of considerably higher value than even the above figures would indicate. Whitworth, with a compression of the solidifying casting under about 20 tons per square inch pressure, obtained castings ranging from 80,000 to 150,000 pounds tenacity, with elongations ranging from 35 to 14 per cent.

Similar figures may be obtained by drop forging, and it may be confidently anticipated that the rapid improvement now in progress in the manufacture of

this class of metals will soon give us maximum tenacities in masses of large as well as small sections, and bring that maximum up to and above the highest yet attained in the smallest sections. It is to-day possible to secure such castings as the above with a ratio of tenacity to weight of from 150 to 300, and capable of carrying a length of their own sections not less than 25,000 and possibly as great as 50,000 feet, and from equality with aluminium up to twice its value. Such casting are, therefore, to-day available for the frames and cylinders and other stationary and intricate parts of the machinery of aeronautics, such as cannot, as a rule, be practically and economically made of the forged metals.

Aluminium, from which great things have been expected in aerial navigation, has a density of 2.6. It melts at about 1200° F., passing through a pasty stage, like wrought-iron, above the red heat. It can be welded either cold or at temperatures between 200° and 400° F. Cold rolling, hammering and wire drawing harden and strengthen the metal greatly, sometimes doubling its strength and making it equal to steel of 150,000 pounds tenacity. Its coefficient of expansion is high, being nearly double that of iron, a fact which may prove of disadvantage when the metal is exposed to irregular heating. Alloyed with copper, titanium or silver, its strength is increased by even very small doses to, in some cases, double that of the unalloyed element. These alloys also have high conductivity—a very important matter if, as seems not at all improbable, electrodynamic machinery may at some time be used for aeronautic work. The alloys of aluminium have been as yet comparatively little studied with the exception of the bronzes in which the lighter metal is substituted for zinc or tin. Aluminium wire can, it is stated, be already supplied at a tenacity of 60,000 to 70,000 pounds per square inch, and a ductility measured by a reduction of area of 50 per cent. Alloys are predicted having double the former tenacity and with a density not exceeding 3.5.

Aluminium is often introduced into iron with advantage, apparently acting mainly as flux, as it disappears to a very large extent in the working of the metal, and its purifying action is the main indication, in the finished material, of its earlier presence. It is added in the bath in the puddling furnace in the manufacture of wrought-iron immediately before the iron "comes to nature;" it is introduced into the fluid mass in steel making immediately before tapping off, and it is thrown into the cupola at the last moment before pouring in purifying cast-iron. From one-half to two-thirds of the aluminium is lost in the operation, and from one-half to one-third is found in the iron or steel. Sometimes it disappears entirely. The admixture is usually about 0.1 of 1 per cent. The gain by its use is stated to be sometimes as much as 20 per cent.

Aluminium bronzes are usually alloys in which the tin of common bronzes is displaced by aluminium. The percentages of the lighter metal are commonly between 5 and 10; but both larger and smaller proportions have their special values for specific purposes. Their densities range from 8.5 for the "2½ per cent. bronze," to 8.25 for the "5 per cent. bronze," and 7.6 for the "10 per cent. bronze" as cast. The worked metals rise in density to 8.6, 8.3, and 8.85. The best known and most used alloy is the 10 per cent. alloy, which has, when sound and pure, a tenacity of about 120,000 pounds per square inch, an elastic limit at about two-thirds this figure, and an elongation in standard tests of from 25 to 30 per cent., with reduction of minimum section from 25 to 40 per cent. In castings its strength is usually a third less than the above, and its ductility less in an equal proportion. The modulus of elasticity is in the neighborhood of 18,000,000 pounds. In compression, its resistance is from 150,000 to 160,000 pounds per square inch. With 5 per cent. aluminium the alloy has about three-fourths the strength above given and 50 per cent. more ductility. These alloys can be forged like

wrought-iron or steel, at a full red heat, and are unaffected by high temperatures. Aluminium and its alloys are annealed by slow cooling.

The introduction of copper into aluminium increases its density slowly and its strength rapidly. Each 1 per cent. raises the density about 0.025, the computed increase being 0.06 and the tenacity one-third; 6 per cent. copper giving an alloy of double the tenacity of the pure aluminium, and but 5 per cent. increased density. The maximum effect of the dosing with copper is seen to be found at about 6 per cent. copper, 94 aluminium. It is, however, possible that other changes may occur at other proportions as yet unstudied. The quotient of the tenacity by the weight per cubic foot being, for the best alloys above given, about 300, it is obvious that they may serve our purposes better than the pure metal and even better than steels of above 120,000 pounds tenacity. The 6 per cent. alloy will sustain a pendent length of its own substance of about 40,000 feet or nearly eight miles.

Magnesium, although still a rare metal and somewhat costly, has always seemed to the writer of this paper, a possible rival of the more common metals for light construction. It is lighter than aluminium, its specific gravity being 1.74, but its tenacity is only 22,000 to 32,000 pounds to the square inch, so that it would sustain from 28,000 to 42,000 lineal feet of its own substance. It seems more likely, therefore, as in the case of aluminium, to prove more serviceable in alloys than pure; but although the writer has been experimenting with the metal for about thirty years he has not yet identified alloys which would be valuable for aeronautic constructive purposes.

Manganese, chromium, nickel and silicon have also found application in the arts as alloys both in bronzes and in some varieties of steel. They impart to the latter various qualities, such as increased toughness, hardness, resistance to penetration, etc., but without very materially increasing its tenacity, so that they cannot be said to be superior to carbon as an alloy for steel intended for aeronautic constructions.

Conclusions from what has preceded seem very clear and unquestionable as far as the most important matter in hand is concerned. Steel is, for general use, the most promising of all the metals yet known. For the motor machine of any system in which lightness is a primary object and strength even more essential than in ordinary construction, the form of the machine must, first of all, be such as involves the employment of tension and compression members as exclusively as practicable, and the entire elimination of every unessential beam or girder; this being the way to secure the highest effectiveness of whatever materials are available. It is usually possible to construct designs in which no other parts than shafts and pins shall be subject to cross-breaking stresses. Frames and running parts may be made of steel; and ties of the best forms for strength combined with minimum sections and volumes. Even irregular parts, such as steam cylinders, may sometimes be built up of malleable material of maximum value, constructively. Drop forgings and castings of steel as high in carbon or other hardening and strengthening elements as is consistent with needed malleability and ductility are better than even any form of aluminium alloy yet discovered, probably better than any alloy of magnesium, where irregular and unmalleable shapes are demanded. Fine steel wires and ribbons having a tenacity of 300,000 pounds or more per square inch, and thin steel tubes of nearly equal strength, represent the highest result yet attained in uniting the two essential properties.

Among the possibilities we are apparently to look for improvements by the introduction of manganese and nickel. Of the two, nickel appears to offer the best results. We can see nothing of value among the alloys of the familiar metals—copper, tin and zinc. We know what is the character of the best possible combination, and that no alloy of these metals is possible possessing unknown properties. We have detected

the "maximum alloy," and have learned its properties. It cannot compete with steel in the principal parts of such machinery as we have in view. Of the rarer metals, aluminium has been expected to give a great advantage ; but we find it far inferior, both in itself and in all its known alloys, to the best steels. Magnesium, a still more promising but much less well-studied metal, gives evident promise of competing successfully with aluminium, both in lightness and strength and in the combination of the two qualities, for such machinery.

For the hull of the air ship, and for other vessels requiring similar properties, it seems very possible that some such substance as the paper employed for racing boats, perhaps even some of the aluminium and other alloys, or those of magnesium perhaps still more possibly if not probably—substances which combine a certain stiffness and substantiality with lightness, and adapt themselves especially to the production of such forms of construction, may answer the purpose. This is quite a different matter, and time and trial only can decisively settle this question. It would at the moment, however, seem probable that steel in thin sheets will prove unrivaled for even such parts as these, and the gist of the whole matter may be summed up in the statement that steel, in its various known grades and qualities, is to-day the one unrivaled substance for all constructions, and that the problem of the moment is the finding of simple and cheap methods of forming of that metal the parts and shapes desired without loss of its wonderful combination of strength, ductility, resilience and comparative lightness as illustrated by the best qualities shown, and, at present, only in small sections. That is to say, we have yet to learn how to secure the real, the intrinsic—if I may use that word—the intrinsic strength and resilience of the metal in all forms and in whatever mass may be demanded.

Meantime whatever the outcome of our as yet incomplete or unattempted researches in these fields, we are able to say that even with known materials and known methods of construction of familiar designs, the problem of motive machinery is practically solved, and that we can to-day build motors of steel that excel those of nature, whether of fish, beast or bird, in their combined lightness, power and compactness. The problem of aviation to-day is no longer one of weight and power of motor ; although it would be folly to assert that there is not much to be done in that direction. Should it prove ultimately possible to construct the air-ship and its various accessories, we may now feel sure that it will not be that hitherto apparently greatest of all visible obstacles, excessive weight of motor-machinery as compared with that of the birds, which will impede progress. The problem for the hour is now, for aeronaut and aviator alike, that of the construction, and especially of the management of the hull and of the propelling wings or screws of the floating or the self-supported air-ship.

REPLACING A DAMAGED ENGINE FOUNDATION.

By Charles A. Hague.

IT happens, not infrequently, nowadays, and it probably did in other days, that improvements, extensions, or repairs must be made with as little delay or derangement as possible of methods and facilities in actual use. We see this illustrated upon a large scale in the skillful manner in which a railway station may be transformed from a small, inadequate affair into a magnificent lofty structure, without interfering at all with the regularity of trains, and, to a very slight degree, with the comfort of passengers.

The experience of the writer detailed in these pages, although of humble extent as compared with the accomplishments of a large railway company, involves precisely the same essence as far as expedition is concerned. A large mill engine had been erected and put in operation, and, as often happens in manufacturing plants that have grown from small beginnings, the general arrangement up to any certain date was not as good or convenient as would have been the case had the full-grown establishment been designed all at once. The consequences of this gradual development in this particular case had resulted, among other things, in locating the steam cylinder of the engine referred to, and framing of the same, at one side of a heavy brick wall already in existence, and the fly-wheel at the other side, the crank-shaft extending through a hole in the brick wall. This, in turn, located the wheel as closely as it could be placed to the foundation supporting the outboard pillow block, forcing this outer foundation to carry a much larger proportion of the weight of the wheel than is usual. Further, to avoid the weakness of an unduly long shaft, already extended beyond ordinary limits, the outer pillow block was located so near to the edge of the foundation that the edge of the pillow block cap-stone coincided with the inner edge of the foundation. Finally, this cap-stone of the outer pillow block was 36 inches wide, and the centre of the length of the journal was 18 inches only from the inner face of the foundation pier. The width of the pier was 60 inches, so that the centre line of vertical pressure was 18 inches from the side of the foundation next the wheel, and 42 inches from the outer line of the pier.

The result, apparently not foreseen, was that the foundation pier, in settling, was forced to incline toward the wheel, causing the journal to heat either at the collar at its inner end, or by reason of its tendency to "ride upon the point," or outer end. As might be expected, there was also a tendency to heat at the collar of the main pillow block journal at the engine frame. An attempt was made to transfer a portion of the pressure to an outer wall of the building by means of a heavy bracket casting and a turn buckle rod; but, although this alleviated the trouble slightly, it was perfectly evident that some more heroic remedy must be applied, and after considering the subject carefully, the writer decided that a new foundation must replace the first one, and must be so designed that the centre line of pressure must fall in the centre of the base of the pier, at least as far as the cross section was concerned. This having been settled, it remained to carry out the idea with the shortest possible stoppage of the engine, and, a few days' shut-down for annual inventory being about sixty days ahead, that time was determined upon to make the change, the intervening sixty days being utilized in preparations for the new work.

Fig. 1 shows the foundations as

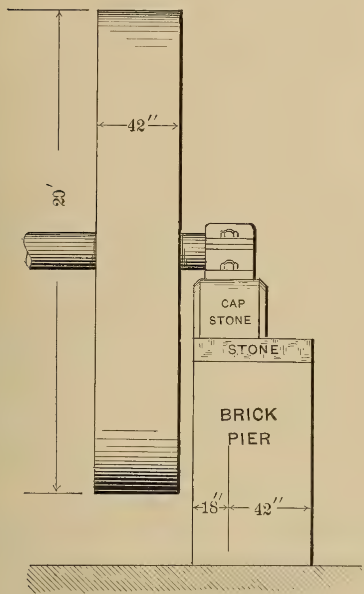


FIG. 1.—THE FOUNDATION AS ORIGINALLY BUILT.

originally built. The foundation consisted of a brick pier laid in cement, 8 feet 6 inches high, topped with 12 inches of cut limestone, making the pier proper 9 feet 6 inches high. The pier was surmounted by a cap-stone, or base, for the pillow block, a solid block of cut Bedford sandstone, 7 feet long, 3 feet wide, and 30 inches deep, rounded at the upper ends, and beveled. The anchor bolts for the pillow block extended downward to within 18 inches of the bottom of the pier, and were arranged with suitable washers and washer stones built into the pier. Pockets in the brick work afforded access to the lower ends of the bolts. The length of the pier was 12 feet, and its thickness 5 feet. The illustration will convey the idea very clearly that, with anything short of rock bottom, the liability is very great of the pier tipping toward the wheel, with a consequent pinching of the shaft laterally, between the main pillow block on the engine frame and the outer bearing. When the trouble had become unendurable, and a general examination was made, it was discovered that the pier was badly cracked on account of the unequal and unprovided-for strains, thrown into the masonry by reason of the tendency of the shaft to ride upon its point, and so tend to crack the pier transversely at the line of the washer stones near the bottom of the mass. These cracks, of course, extended, incidentally, to other parts of the pier. As a matter of fact, the pier was badly cracked, in a manner beautifully consistent with the lines of strains imposed by the abnormal conditions.

The trouble, therefore, having become serious, and the cause located, the next step was to design a new pier, calculated to successfully meet the requirements. The simplest, and at the same time most scientific, course to pursue was to draw a plumb line through the middle of the length of the journal, and have the base of the new pier equally distributed transversely on each side of such a line. It was decided to make the new pier of stone. The drawings were made, and every stone was laid out and numbered, proper allowance being made for cement joints. All necessary drilling of anchor bolt holes was done, and arrangements were made for tying all stones together in the same course laterally, by means of

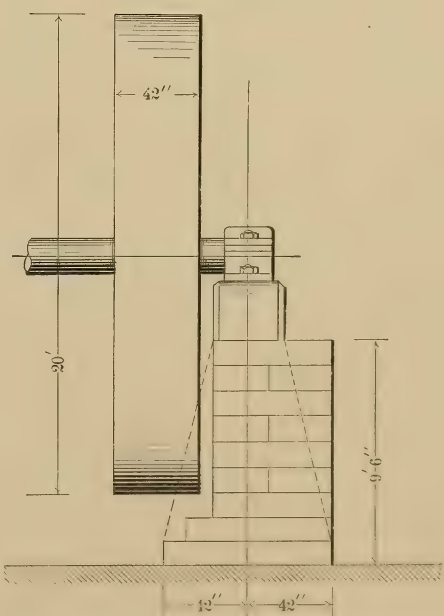


FIG. 2.—THE NEW FOUNDATION.

suitable iron staples. The result was most successful. The entire work of tearing out the old pier and putting up the new one entailed only eight idle days upon the engine, this time being two days longer than it would have been but for the extreme difficulty of tearing apart the lower portions of the old pier where the cement had been thoroughly set and remained damp and cool.

One of the most interesting parts of the undertaking is the manner in which the fly-wheel and shaft were supported during the operation of changing foundations, so as to leave the space beneath the wheel entirely clear and free from blocking; but before going into this part of the subject, attention is directed to Fig. 2, showing an end elevation of the new foundation.

It will be observed that the foot course of stone, 12 inches thick, is placed equally on each side of the centre line, and necessarily extends beneath the wheel. The second course of stone recedes a trifle at its inner edge, but extends outward as far as the foot course. Then the rest of the pier proper extends upward practically the same as in the old pier, the cap-stone and pillow block being central the same as the foot course. The real philosophy of the new support is indicated by the dotted lines; that is, in the new foundation the pier is practically as though formed with sides sloping from the cap-stone to the foot course; the additional advantage is secured of having the centre of gravity of the pier outside of the plumb line passing through the middle of the journal's length, thereby throwing any tendency to tip, away from the wheel instead of toward it, as before, and so avoiding any chance of pinching the shoulders of the shaft.

The bonding of the stones forming the pier, laterly, by means of staples, already referred to, was done by forming long, low, flat staples of 1½ x ½-inch flat iron, and setting the staples in cement in holes drilled in the stones; the body of the staple being let into the surface of the stone so as not to interfere with the setting of the succeeding course. The cut-stone forming the top of the old pier, was used in the same place upon the new pier, and, of course, the cap-stone was worked in in good shape. The anchor-bolt nuts were imbedded within cast-iron boxes by pouring melted lead around them after having been properly set in place, the washers being formed by the upper surfaces of these cast-iron boxes. No attempt was made to provide access to these lower nuts after the foundation was completed, as from the arrangements stated, the anchor bolts could be readily screwed into or out of the lower nuts, without disturbing the latter.

When this new foundation was first contemplated, it became obvious that some means must be provided for supporting the wheel and shaft, weighing about 50,000 pounds, clear of the ground, so as to enable the workmen to remove the old and build the new foundation in the shortest possible time. Blocking would have interfered with the proper accomplishment of the work considering the limited space, even though the time had been no object. There was no opportunity of placing timbers through the wheel arms, and keeping them there during the operation, for the simple reason that the foundation pier itself was the only place upon which the timber could be supported, and, all things considered, it was deemed best to suspend the shaft and wheel from the floors above. The under side of the first floor was about six feet above the top of the wheel, and there was a second floor about twelve feet above the first one. The span of the first floor timbers being rather extreme, in view of the fact that the weight would be somewhat concentrated, a pair of heavy tie rods were extended from the under side of the first floor beams to the upper side of the second floor; then, the weight was suspended from the first floor, thus securing the strength of both floors for the purpose. The means employed in supporting the weight were novel, and were developed in considering the fact

that it was expedient and necessary to maintain the shaft constantly in normal position. Chain or rope tackle were deemed undesirable, partly because a large gang of men would be at work directly beneath the suspended wheel, and partly because constant attention and adjustment would be necessary, in all probability, to meet the stretch and give of blocks and falls, introducing elements of uncertainty alike dangerous to the men and machinery.

The supporting rods consisted of two long lengths of 2½-inch cold rolled

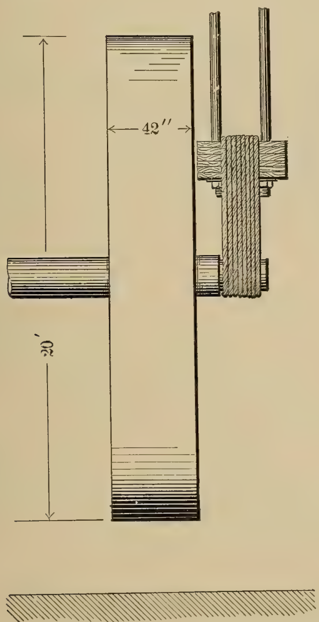


FIG. 3.—HOW THE WHEEL WAS SUSPENDED.

shafting, with square threads of ⅜-inch pitch, cut upon each end of each shaft, leaving, after proper deduction for threads, a factor of safety of ten. Forged wrought-iron nuts were made to fit the threads, and heavy wrought-iron washer plates maintained an unvarying distance between these long bolts, both at their upper and lower ends. Three thicknesses of 3-inch oak plank were laid across the top of the first floor, surmounted by one of the wrought washer plates. Then the bolts formed of the 2½-inch shafting, were passed down through the floors, and to within about 3 feet of the engine shaft, outside of the wheel, or directly over the outer journal. The lower ends of these bolts passed through a header made of six thicknesses of 3-inch oak plank; the distance between the bolts being 24 inches, centre to centre, and the under side of the header was protected by another of the wrought washer plates.

The wheel was first blocked up so that the outer pillow block could be removed. Then a sling was formed by passing turns of 2½-inch diameter manilla rope under the journal of the shaft and over the oak header, until the space upon the header between the long bolts was filled closely; after this, the ends of the sling were secured. As will be seen the device formed a sort of jack screw in suspension, and a few turns of the upper nuts brought the sling up taut and took the weight of the wheel and shaft. The margins of safety were purposely very wide, and this was as much to prevent settlement of the wheel and possible damage to the main pillow block at the engine frame, as for actual safety of the men at work. The idea was to provide a support as nearly as possible invariable as solid blocking. It will be observed in this connection, that the iron rods or bolts extended from the place of their support nearly down to the shaft itself, leaving a very short distance to be filled in by the rope, thus reducing the possible stretch to the lowest terms. As a matter of fact, the stretch and settlement amounted to but little, and after the shaft had been watched a day or two, tried with a level, and screwed up when necessary, it remained constant for the balance of the time of suspension.

The inexpensiveness of the supporting device was not the least of its merits; after the affair was over, the shafting, with the screw ends cut off, was utilized in the factory, and even the threaded portions were used in forming a bending clamp. Fig. 3 shows a portion of the suspension device supporting the wheel, with the foundation

removed. There was no cutting of the building necessary, beyond boring some moderate sized holes in the first and second floors. The material for the foundation was all brought upon the premises, before the factory was shut down, and the work was carried to a speedy and satisfactory completion.

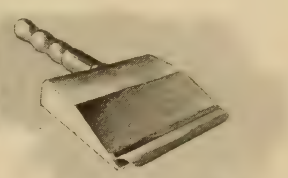
Current Topics.

STORING wind power has, for years, been one of the pet subjects of inventors, and many and wonderful have been the schemes proposed to accomplish the work. One of them, hailing from the sandy plains of the western part of the United States, was to have a windmill drive a belt and bucket conveyor to carry sand up into a large tank or hopper, somewhat after the manner in which grain elevators carry wheat. A stream of sand was to be let out from this bin upon a large overshot water wheel and cause it to turn, just as it would under the weight of a corresponding volume of water. When there was a good, steady wind, sand was to be stored up for use during succeeding calms, and power was thus to be made available continuously, with the specific object of driving a number of arastras, or ore mills, which were located in a sandy district where only sufficient water for drinking purposes and for moistening the ore to be operated upon could be obtained. Like the winding up of springs, the compressing of air and other unlikely wind power storage suggestions, however, this sand power scheme has come to naught, and its promoters have been obliged to seek other fields and pastures new.

THE iron foundrymen in their associations are now wrestling with the question whether or not chemistry is of any value in iron foundry work. The great majority hold that it is not, and that practical experience is the only thing that will insure good castings ; but a few "advanced thinkers" are urging the claims of chemistry. The foundrymen are now going through the experience that the blast furnacemen went through about twenty years ago. About that time a few of them began to employ chemists, but the old timers held that the only proper way to test an iron ore or a fuel was to try it in the blast furnace. Inside of ten years every important iron works in the country had

its chemist, and all the iron ore was bought on its chemical analysis. In the iron foundry, however, too much must not be expected of chemistry. It will not tell us yet what compositions of iron to use for different sizes, shapes and strengths of different castings, for the quality of a casting depends, not only on the quality of the raw iron used to make it, but on the changes in quality that may take place in it in melting, pouring and cooling. But having once obtained castings of a desired quality, and having reached a uniform practice in molding, melting, pouring and cooling, then to insure duplication of the desired results it is necessary that the composition of the iron be the same, and this chemistry enables us to insure, giving also the further advantage that it enables us to substitute for one lot or brand of pig iron another of the same analysis, or a cheaper mixture whose combined analysis is the same.

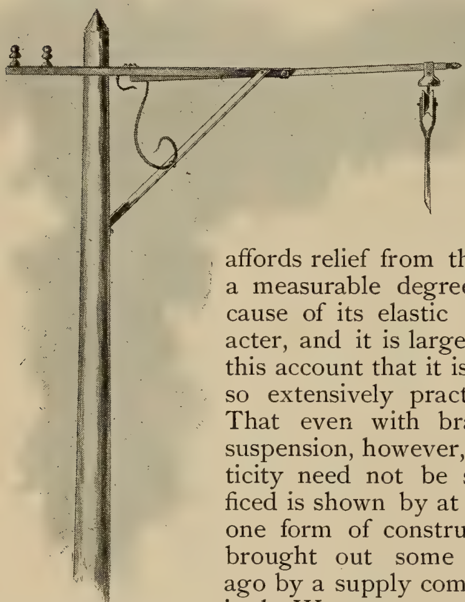
RAILROAD car cleaning by compressed air is one of the latest developments of compressed air application, of which, in late years, there has been almost endless multiplication. Attention was drawn to it recently in a report of a committee of the Master Car Builders' Association detailing the growing use of compressed air in car shops and yards, and illustrating various forms of pneumatic hoists, pumps and other labor-saving apparatus for railroad service. Not the least interesting among these were the dusting nozzles, one of which is here shown, and which, in three instances at least—on the West Shore, the Erie, and the Chicago, Rock Island & Pacific lines—have been put to use with such good results that they would seem to promise the early relegation to the railroad curio scrap heap of the conventional rattan beater and brush. These compressed air dusters, as shown by tests made by the committee, effect a decided saving in time in cleaning car cushions, the average time consumed by two men, one operating one of the nozzles and the other handling the seats, in removing the dust from plush and springs of 200 seats, cleaning them perfectly, being from 27 to 33 seconds for each seat. The air used in these tests was supplied from a reservoir at a pressure of from 60 to 90 pounds per square inch. Another test at cleaning by hand in the usual way, with beaters and brushes, showed the time necessary for each seat to vary from three to four minutes, the air dusters thus effecting a time saving of about 85 per cent.


A DUSTING NOZZLE.

THE money value of hands and fingers has been made the subject of an interesting estimate by one of the German miners' accident insurance companies. According to this, the loss of both hands represents a loss of 100 per cent. efficiency, or, in other words, the whole ability to earn a living. Losing the right hand depreciates the value of an individual as a worker 70 to 80 per cent., while the loss of the left hand represents from 60 to 70 per cent. of the earnings of both hands. The thumb is reckoned to be worth from 20 to 30 per cent. of the earnings; the first finger of the right hand is valued at from 14 to 18 per cent.; that of the left hand, at from 8 to 13.5 per cent. The middle finger is worth from 10 to 16 per cent. The third finger is valued at no more than from 7 to 9 per cent., while the little finger is worth from 9 to 12 per cent. The difference in the percentages, it is explained, is occasioned by the difference in the trades followed by the injured ones.

ANENT the matter of electric street car trolley wheels jumping from trolley wires, often at the most inopportune moments, to which reference has several times been made in these pages, it may

not be amiss to note that too rigid suspension of the wire is, in some cases, a probably not unfruitful cause of this annoying trouble. With many forms of bracket suspension, the wire is held so rigidly at the points of support that the trolley wheel receives a severe blow in passing, which prompts its sudden jump into space, and incidentally injures both trolley wheel and clamp or insulator. Span-wire construction



A FLEXIBLE BRACKET ARM FOR TROLLEY WIRES.

affords relief from this in a measurable degree because of its elastic character, and it is largely on this account that it is now so extensively practiced. That even with bracket suspension, however, elasticity need not be sacrificed is shown by at least one form of construction brought out some time ago by a supply company in the Western part of the United States. In this, as will be seen from the little sketch annexed, the bracket arm that supports the insulator and trolley wire is pivoted at its centre so that the wire is suspended in what would seem to be an even more flexible manner than that attained with the span-wire system, since the end of the supporting arm, next to the pole, acts as a counterweight, enabling the trolley wire to yield to the upward pressure of the trolley wheel with little jar or shock. Practical test on one of the large inter-urban electric railroads is said to have fully demonstrated the merits of the arrangements, so that, where bracket suspension must be adopted, the device may be found a very desirable means of relief from some of the trials which beset the electric street railroad manager's life.

WHILE on the subject of trolley lines, attention may be directed to a novel feature found in a road opened for traffic a short time ago at the town of Chemnitz, in Germany. Poles for brackets or span wires were there entirely dispensed with, and the span wires were strung from ornamental rosettes fastened to the walls of the houses along the streets, the rosettes having hooks to which the wires were attached. The owners of the houses, without exception, preferred to allow the free use of their houses as supports rather than have posts on the sidewalks, and the rather unique result is a trolley line without poles—something unknown in any other place so far as we are aware.

AN interesting chapter has just been added to the literature of electric motor applications in the shape of a report by United States Consul Chas. W. Whiley, Jr., on applied electricity in the industries of St. Etienne, in France. St. Etienne may well be called a workingman's town. Fully three-fourths of its 133,000 inhabitants derive their support from the mine, the gun factory, the foundry and the loom. Of this large body of wage-earners the weavers number about 30,000, and of the 18,000 looms in St. Etienne, the greater number are owned by the individual weavers and worked by hand in their own homes. Until very recently the ribbon-weaver, laboring in this way, could see no room for improvement in the mechanical execution of his work. From time immemorial the long bar had been worked by hand. Brought up to it from childhood, and inheriting the prejudices of his class, it was difficult to convince this member of an ancient guild that any advantage could be gained by the substitution of any other power for that of his own sinewy arm. Of late, however, his eyes have been

opened to the wonders of that subtle agent which is so rapidly transforming the mechanical work of the world, and to-day it is not a rare occurrence to find an humble weaver who can talk to one of dynamos and motors with a surprising degree of intelligence. Already, according to Consul Whiley's account, over sixty looms are worked electrically and a considerable increase in this number is expected within the next few months. The current is furnished by the local Edison company which, for several years past, has supplied the lights of a large number of shops in the town.

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So far as the large ribbon factories of St. Etienne are concerned, they are, as a rule, operated by steam power, but at least one of them, of more progressive tendency than the rest, has declared itself emphatically in favor of the newer method of driving by installing electric motors for all its work. The factory has about 100 looms for the manufacture of the various styles of ribbons—silk, velvet, fancy ribbons, etc.—and a number of others for the making of plush. All these are worked by electricity, furnished by two dynamos on the ground floor. The same firm has another factory about fifty miles from St. Etienne, and this too is operated electrically, the current being transmitted from a water-power generating station eight miles away. The results arrived at with the installations are said to have thus far proven themselves most satisfactory in every way. Regularity of speed,—a very essential requisite in mills of this kind,—has been found to be attained perfectly with the motors, the work has been carried on without the slightest mechanical hitch, and the operating costs, finally, have dwindled down most perceptibly, demonstrating, altogether, that the merits of electric transmission had been by no means overrated.

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Numerous "automatic" telephone systems have been devised and a number are seeking an introduction to the public with every indication of a welcome. That any two among many subscribers may open communication with each other without the intervention of "central," is a novel and gratifying idea. In one of the systems, connection between each subscriber of a group and the main line is made by attaching the wires leading to each subscriber to brushes or contact ships which engage pins, or contact points, upon a revolving cylinder in a manner similar to that employed in music boxes. The contacts are so arranged that each subscriber is in connection with the main line, say, once every minute, or every two minutes, according to the number of subscribers in his group. The connection of any subscriber is indicated by visual, or audible, signal, and by moving a switch he can then stop the motor which rotates the commuting, or contact, cylinder. As the motor stops, another motor is put in motion which will run for a predetermined time, say five minutes, then automatically stop and restart the contact motor, cutting out the subscriber, and giving all other subscribers in the group an opportunity to connect with the main office before the subscriber who has been talking can have another opportunity. By listening the subscriber can distinguish the audible signals of the other group to which he has been connected, and when he hears the signal corresponding to the subscriber with whom he wishes to talk, he can arrest the motion of the contact cylinder in that group, and will then be in connection with the one whom he desires to reach. No other subscriber in the group can hear what is being said between the two thus connected, and "central" cannot ask, "Are you through?" The office of "central" is mainly to establish connection between the various groups, each group of several subscribers having a single all-wire circuit connection with the central office. But how the subscribers in a "group" are to open communication with one another, the inventor of the system sayeth not.

A PECULIARLY novel and simple combination of an engine and electric light dynamo is now in operation at the American Line pier at New York city. The novelty consists in the fact that when running at any load, under normal conditions, a governor on either the engine or dynamo, is entirely dispensed with. The combination consists of a Sturtevant double cylinder engine, and a 50-light, series arc machine, coupled direct to the engine shaft. This novel departure from existing methods is made possible by the peculiar properties and characteristics of the constant-current arc machine. As is well known, when a certain number of lamps on a series circuit are supplied by a machine of this type, any addition to, or decrease in, the number of lamps on the circuit will decrease or increase the current supplied by the machine to the circuit, owing to the fact that the more lamps are added to the circuit, the higher its resistance becomes. In order, therefore, to keep the current constant, it has been the practice to provide upon all arc machines an automatic regulator, which would so operate upon the dynamo, in proportion to the number of lamps that were upon the circuit, that the voltage supplied by the dynamo would vary with the number of lamps upon the circuit—the more lamps, the higher the voltage, each lamp taking about 50 volts. The speed of the dynamo and engine in all such cases is always kept constant by the governor on the engine, and the variable voltage of the dynamo is, therefore, a result of the variation in the strength of the field magnet, or of the different positions of the brushes upon the commutator, or, perhaps, a combination of both.

IN the arrangement here spoken of the variable voltage necessary for the variation in load is produced by varying the speed of the machine. As the torque in any dynamo is proportional to the ampere-turns in its armature with a constant field, and to the strength of the magnetic field, any variation in the current supplied by the armature will increase or decrease the torque. When lamps are, therefore, added to or taken off the circuit supplied by the machine, the current is proportionally decreased or increased, which correspondingly affects the torque. When a load is added, the current is decreased ; this decreases the torque at the shaft of the dynamo; and, therefore, the load on the engine, at a certain speed, and the tendency is consequently for the engine to increase its speed until the dynamo has been speeded up to the point where the voltage generated by it will be brought to such a point as to send the same current as before through the higher resistance of the circuit caused by the additional lamps added to it. If lamps be taken from the circuit, or the load be decreased, the current will be increased, and with a certain speed this will increase the load upon the engine. The tendency, therefore, in this instance, would be for the engine to slow down until the voltage of the dynamo had been reduced to where the current sent through the circuit and armature of the machine would return to the same point as under normal conditions and again balance the torque of the engine. In fact, the torque of the engine and the torque of the dynamo always are balanced, and variation in load is made up for by a variation in speed. The dynamo does not alone govern itself as in other cases, but it also actually governs the engine. The normal speed of this engine at full load is about 500 revolutions. As a safeguard against a broken circuit, which would at once throw off all the load, a small governor is used, but it is so set that it begins to act only at about 550 revolutions, or above any speed required even for the maximum load that can be supplied by the dynamo. With such an arrangement of dynamo and engine, it becomes highly important that the boiler pressure should be kept constant, and this would seem to be the principal difficulty to its successful operation. The arrangement would, perhaps, not be applicable in cases where the load upon the dynamo changed very suddenly and greatly, but

for many cases it would seem to be feasible, particularly in isolated plants where the steam pressure can be kept fairly constant. It may not be amiss to point out that this method of dynamo regulation is not of recent origin, and is described in Prof. Thompson's book on "Dynamo Electric Machinery."

WITH all that has been said of early ocean steamships and the historic trans-Atlantic voyages of the paddle steamers Sirius and Great Western, away back in 1838, the fact is less well known that the real forerunner of the mammoth screw steamers of the present day was the steamship Great Britain, commenced in 1839 and floated in 1845—the first screw steamer to cross the Atlantic. Like the Great Western, to which, perhaps, belongs the real honor of having opened to commercial and passenger traffic the great Atlantic ferry of to-day, though preceded by four days by the Sirius, which latter, however, was withdrawn after a second voyage, while the former continued successfully in service for several years, the Great Britain was built by the Great Western Steamship Company. What manner of boat she was may be gathered to some extent from the accompanying illustration, reproduced from a recent issue of The Engineer of London, to which we are indebted also for the appended particulars. Her length over all was 322 feet; her extreme breadth, a little over 50 feet; her depth, 32 feet; and her displacement at a load draught of 18 feet, 3618 tons. Her first voyage from Liverpool to New York was commenced on July 26, 1845, and occupied nearly fifteen days, the average speed during the run being nine knots an hour. After remaining on view about a fortnight in New York harbor, the homeward passage to Liverpool was successfully accomplished. Voyages back and forth were made with satisfactory results until the autumn of 1846, when, on a very dirty night in the month of September, she was stranded off the coast of Ireland. There she remained for eleven months, through a tempestuous winter, until she was finally floated in the following autumn and taken to

THE GREAT BRITAIN. THE FIRST ATLANTIC SCREW STEAMER, 1845.

Liverpool for repairs. After a complete overhaul the vessel entered on a new era in her existence, being put by new owners into the Australian trade, where she retained the name of being a splendid sailer and a fairly successful steamship. Entering upon this trade in 1853, she remained in it for twenty-one years, until the requirements of modern passenger transit had outgrown her capabilities. Finally her propelling machinery was removed, and only a few years ago she was seen passing up the English channel as a full-rigged sailing ship. She is probably still in existence, having last been known to do duty as a coal hulk in one of the Pacific islands.

NOT the least interesting of her many interesting features was found in her propelling machinery. The main crank shaft was of wrought-iron, seventeen feet long, its diameter at the middle

part being 28 inches, and at the bearings, which were 30 inches long, 24 inches. Through this shaft, its cranks and crank pins, a hole was bored through which a stream of cold water was constantly injected to keep the main bearings cool. Upon this main shaft was keyed a toothed drum, a little over 18 feet in diameter at the pitch line and 38 inches wide, around which,

THE AUGUSTA VICTORIA, AN ATLANTIC LINER OF TO-DAY.

and a smaller drum 6 feet in diameter, keyed on a shaft immediately below it, four sets of pitch chains worked, the operation of which was remarkably smooth and noiseless, accounted for by the fact that what served the purpose of teeth in both drums, were bars of teak wood in the larger, and lignum vitæ in the smaller, let into recesses in the rims of the former and the boss of the latter. The pair of direct-acting engines, with 88-inch by 6-foot stroke cylinders, being intended to be driven at a maximum speed of 18 revolutions per minute, the drums were speeded to give nearly three revolutions of the screw shaft to one of the engine shafts. Engineering opinion as to the proposed application of pitch chains for the transmission of the power of the engines to the propeller shaft was at that time somewhat divided, there being no previous experience in that direction, but the results of their working during the preliminary trials and subsequent voyages of the ship amply proved their adaptability to the purpose, there being but one link of the number employed that ever showed signs of distress through strain. Looking back along the fifty years that have passed since the Great Britain was completed, it can be said, with little fear of contradiction, that, despite the great strides which have been made in the designing and building of high-speed vessels of large power and great tonnage, the principles of construction which have found their development in these structures were anticipated in this early ship.

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SILVER MINING IN SOUTH AMERICA.

By Otto F. Pfordte, M. E.

THE silver ore deposits of the famous district of Cerro de Pasco, in South America, were discovered in 1630 by Huari - Capcha, an Indian shepherd, and in the early part of its history the district yielded enormous riches. The records from 1784 to 1846, excluding five years, 1821–25, during which civil war prevailed, show a product of 2,323,526 pounds of silver, and the value of the total product since the discovery may be estimated at about $565,000,000. In a paper on the Cerro de Pasco mining industry, presented by the author a short time ago before the American Institute of Mining Engineers, substantially what follows was originally published, though additions have been made both to the text and the illustrations.

The town of Cerro de Pasco is in the province of the same name, in the department of Junin, Peru, 14,250 feet above sea-level. The nearest railway station is on the line of the Callao and Cerro de Pasco railroad, at a distance of about three days' travel on horseback. The population of the town numbers about 6000, mostly native Indians. The mines are mainly located in the immediate neighborhood of the town, and partly even under the principal streets, being distributed in several very large open cuts, 250 to 350 feet deep, called tajos, which extend in a nearly direct north and south line west of the town, and are known as Tajo de Santa Rosa, Tajo Tingo or Portachuelo, Cajac Grande, Cajac Chico, Salsipuedes, Avella Fuerte, and several smaller ones. Tajo de Santa Rosa, the largest and most southerly, is closely connected on its north side with Tajo Tingo, while the others are entirely separate and lie northward in the order given, the extreme ends of the series being about a mile apart. Besides these, there are Tajo Descubridora, a short distance east of Sta. Rosa, and Tajo Matagente, about half a mile north of the main plaza in the town of Cerro de Pasco. The names of the tajos have different origins. Santa Rosa is named in honor of a patron saint. Tingo is an Indian word, generally meaning the confluence of two streams, though no traces of a watercourse are visible in that place now. Portachuelo is a Spanish diminutive for door, and may have indicated a cleft or

A MINE IN THE MOUNTAINS.

passage in the rocks. Cajac is an Indian word, and possibly related to the verb cayac, to be. Chico is Spanish for small. Salsipuedes is a compound of three Spanish words, meaning "go out if you can." The tajo is called so on account of the difficulty of any person finding his way out unless well acquainted with it. Avello Fuerte seems to have reference to the conglomerate nature of the rock. Descubridora means discovery. Matagente means "kill people," a name given on account of a great accident when the entire mine caved in and killed from 250 to 300 Indians, whose bodies have never been recovered.

The argentiferous deposit consists mainly of a ferruginous sandstone, while the neighboring country rock is limestone, conglomerate and slate. The judicial fixed point from which all mining claims are measured is a cross erected on a small elevation east of and between Tajos Sta. Rosa and Tingo, called Santa Catalina. This important point, however, has not escaped displacement on account of the cavings in the ground, caused by the neighboring mines, which have thus produced much disorder in the exact boundary lines of the claims. The claims in the tajos are 30 by 60 varas (1 vara = 33 inches) in size. Those not located in the tajos are 100 by 200 varas. The close proximity of the claims and the general disorder underground are causes of frequent quarrels and litigation. At present but little ore is extracted by open cuts, most of the mines being worked by means of small, steep and irregular inclines, of which one entrance sometimes serves for two or three different claims.

The workings are very irregular and often dangerous, as but little care is given to the interior of the mines, except in very bad ground, where small timbers and stones are used for support. The inclines generally receive a little more care. Whenever a richer portion of ore is found, all the ore is often extracted without leaving any bridges or pillars. Hence, large boulders are sometimes seen in the roofs, which appear to be on the verge of falling, and occasionally do fall unexpectedly, so that accidents in the mines are common occurrences.

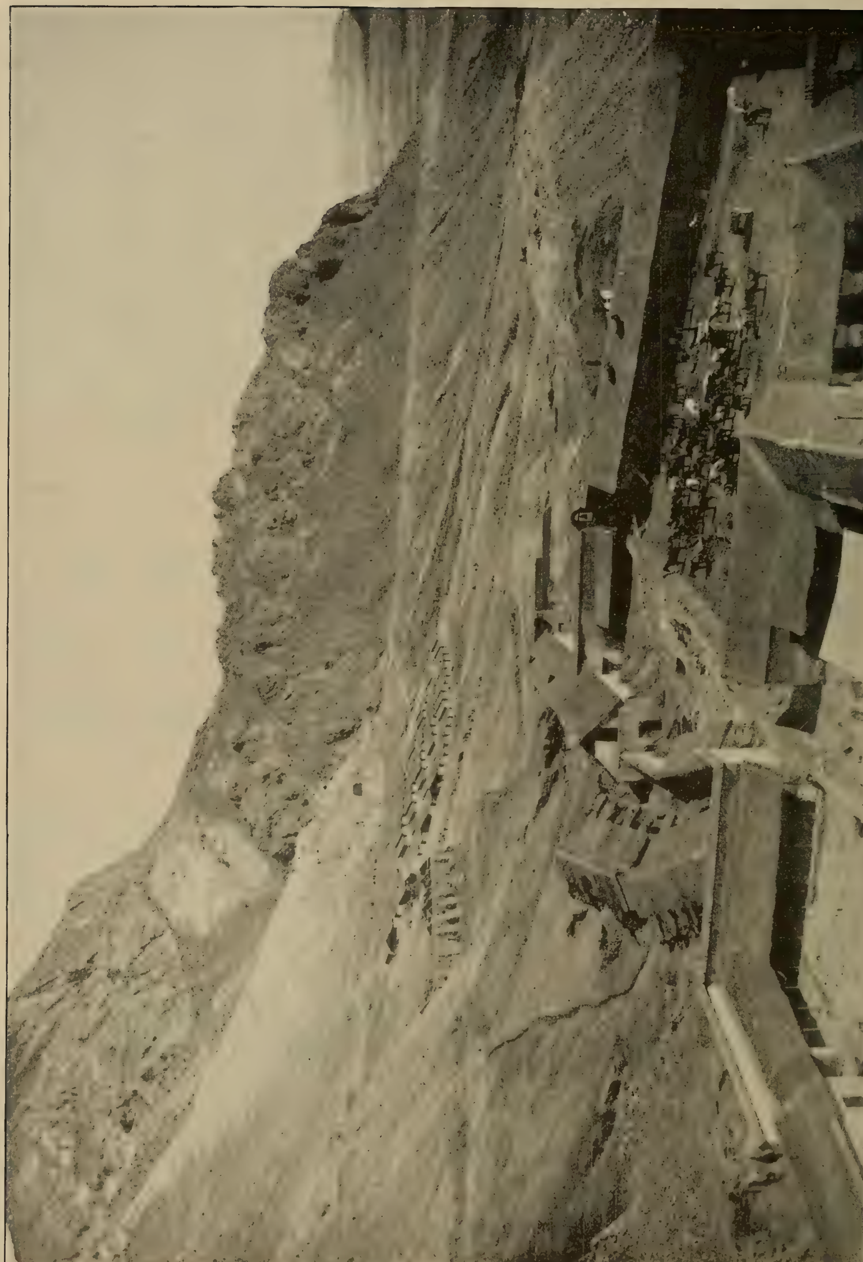
The ores are extracted by means of picks, and then broken with sledges to such a size that they can be placed in large leather sacks holding from 75 to 150 pounds each, and carried out to the

dump. In places where the ground is exceptionally hard, drills and powder or dynamite are used. Hoists or whims are not used, all the ores being taken to the surface by carriers. After the ores have been deposited on the dump, they are separated into three classes, called chancados (ores spalled to a uniform size), cernidos (sifted ores remaining on a ½ or ¾-inch screen), and llampu (the finest passing the screen). The last class contains but two marcos (1 marco = 7.5 ounces) of silver per cajon (6000 pounds), and is rejected. The first and second classes are measured separately in rudely-constructed boxes, three of which are considered as a cajon; and the ore is ready to be sold to the amalgamating works or haciendas, as they are called in Spanish.

During the last century the necessity of drainage became apparent, and a tunnel, the Socabon de San Judas, was commenced in 1780 and completed in 1800. It is 3500 feet long and cost $100.000. Another tunnel, 88 feet below the former, was started in 1806, and up to 1852 had been driven 8250 feet at a cost of $1,000,000. At present its total length is about 2 miles. At a distance of one mile from the mouth, it separates into two branches, aggregating about a mile in length. The Rumillana tunnel, said to be 180 feet below the preceding, or 400 feet from the surface, was started in 1877; it was calculated to be 2600 meters long, of which only about 300 had been completed when work was stopped.

The ores of the district from which by far the greatest portion of the silver is obtained are oxidized surface-ores, called pacos, containing some silver in its native state. By long experience the miners are able to judge the quality of the ore by its appearance, though often the differences are very slight. Frequently lots of ore are purchased by the millman without any special test, he being guided alone by the appearance of the ore and his previous experience with it. Pacos, at present, vary from 4 to 8 marcos per cajon. Ores having less than 4 marcos are worthless, as 4-marcos ore will just pay expenses. In general, the ores sold contain from 5 to 6 marcos per cajon of silver, or, say, from 12½ to 15 ounces per ton. At the bottom of Tajo Tingo a large bank of low-grade iron pyrites is seen, and it is very prob-

THE CITY OF ORURO, BOLIVIA.



A MINING HACIENDA.

able that pyrites will also be found in the deeper workings of other tajos. These sulphides are so low in value that they cannot be worked profitably for silver with the present means.

In some of the older mines copper and iron sulphate crystals and incrustations and iron-oxide incrustations are common. Galena and the richer sulphide ores, which are used by the smelters, are brought from mines which are not in the immediate neighborhood of the town. Samples are taken from the pacos, brought to the dump each day, after they have been spalled and sifted. All the samples of the week, or of a lot, are then reduced and quartered, until a small general sample is obtained, which is ground very fine on a stone plate for the final test. This test, which is merely an amalgamation on a small scale, is used throughout the district, and is conducted as follows:

One pound of the finely ground pulp is moistened; 4 to 5 ounces of salt and a level teaspoonful of magistral, or roasted ore containing copper sulphate, are added and thoroughly mixed by hand. Then, 2 adarmes (each equals 1.8 grammes) of mercury are added, and again mixed. The test is then left for 24 hours, and examined by washing a small portion of it in a shallow earthen plate about 7 inches in diameter. In case too much magistral has been added, the test runs hot, the wash-water becomes milky, and a little lime-water may be added as a remedy. This test is generally run a trifle hot. In 48 hours it is completed, the pulp is carefully washed, the mercury is all gathered, and the amalgam is skillfully separated with the thumb.

The amalgam and the mercury are then either weighed separately or merely judged by the volume of each. If the small globules of amalgam and mercury are equal in size, the ore contains 6 marcos per cajon; if the amalgam is one-half the size of the mercury the ore contains 5 marcos, and if it is but one-third, the ore has 4 marcos at most, and will then pay expenses only. Ores of 5 marcos per cajon are worth from 8 to 10 soles (Peruvian silver dollars) per cajon at the mine, and 6-marcos ore is worth up to 15 soles.

The ore is transported from mine to mill with llamas or donkeys, the former

A MINER'S HUT.

taking 100 pounds and the latter 200 to 300 pounds at a load. If the mills are near the line of the Cerro de Pasco Mineral Railroad, which extends from the Cerro in a southwesterly direction for 8 or 9 miles, over a large plain, and passes by a number of mills, it is utilized for transportation, and the ores are then taken from the nearest station to the mill.

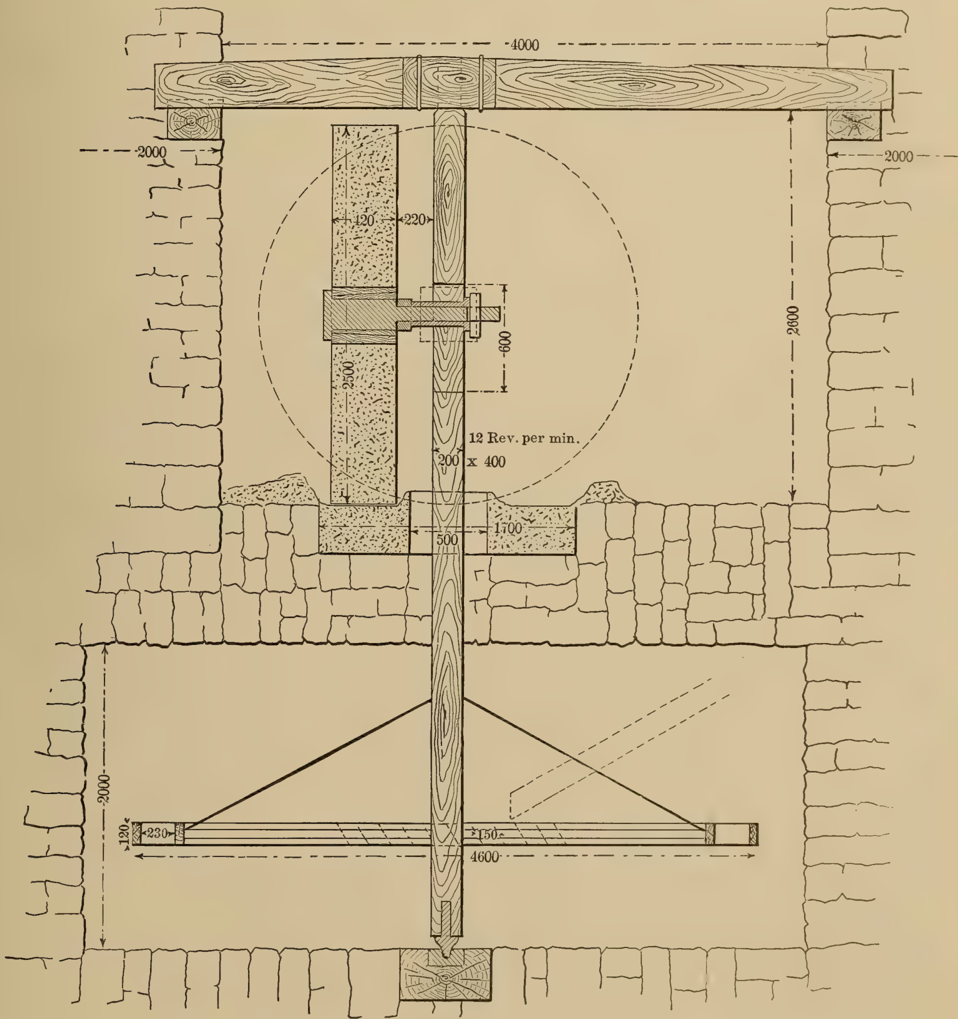
The ores are amalgamated by the patio process in some sixty to seventy mills, most of which are at a distance from the mines. The plant which constitutes a mill or hacienda generally consists of a ditch, a horizontal water-

A HERD OF LLAMAS USED FOR TRANSPORTING ORE.

wheel and Chilean mill combined, called injenio, pulp and slime-settling tanks, built of crude masonry, a number of amalgating patios called circos, on account of their circular shape, which hold 5 cajons each. For continuous operation, each injenio requires 6 circos, 3 of which are emptied and recharged each month. Washing troughs and mercury traps are connected with the circos by means of stone sluices. There is also a storehouse for chemicals and tools, an amalgam filter and mercury trough, and a furnace and retort for distilling amalgam. The smaller mills sometimes lack the latter and use those of their neighbors. The size of the mills varies from one to twelve injenios with the number of circos. The injenio shown in one of the illustrations makes twelve revolutions per minute, and grinds 1½ tons of ore in twenty-four hours. The mill consists of a vertical shaft, the upper end of which revolves in the bearing of a horizontal cross-beam, while the lower end revolves on a pivot. At the lower part of the shaft the water-wheel is arranged in a vault. The upper portion of the shaft contains a slot for allowing a vertical sliding motion to a bearing of the mill-stone pivot, so that the height of the bearing can adjust itself according to the wear of the mill stones, the upper one of which is called voladera, the lower fixed

one being the solera. When a voladera has been worn down to 1.5–1.7 meters in diameter, it is replaced by a new one and further utilized as a solera.

The tabladilla is an inverted injenio in which the horizontal water-wheel is diameter; while in the other the circos are in a square mass of masonry. They are always built adjoining each other in two or more rows, which are separated by a narrow sluice containing washing troughs and mercury traps.



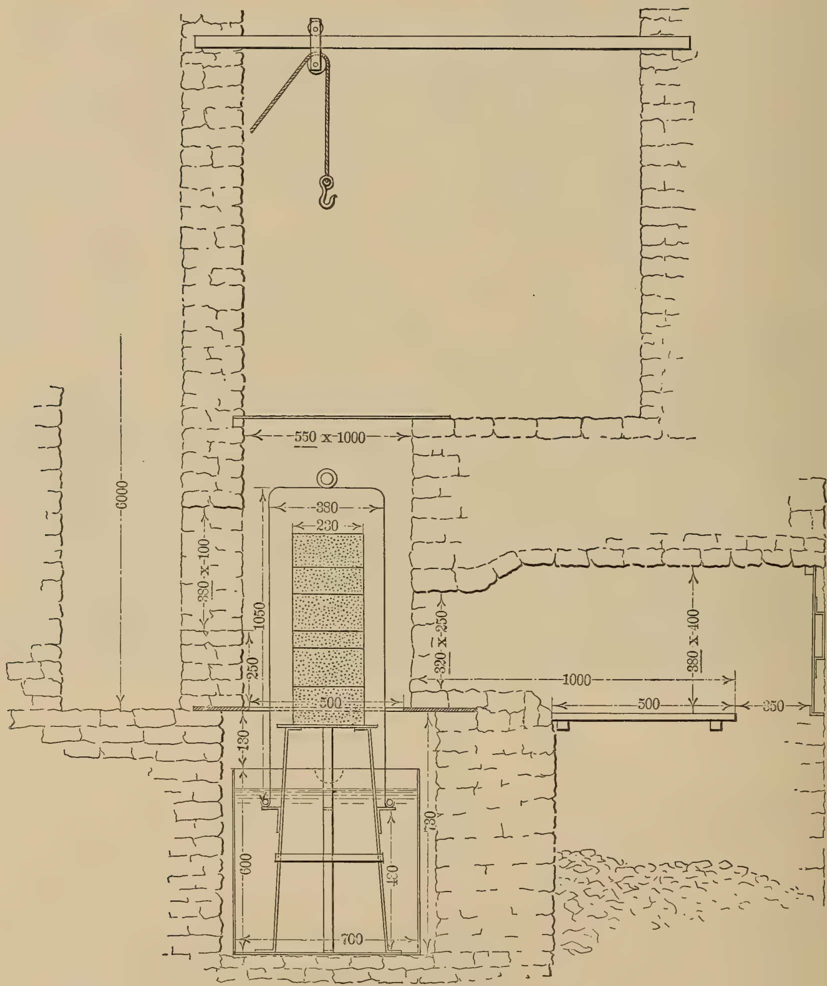
VERTICAL SECTION OF AN INJENIO.

arranged above the mill stones. It is rarely used. Its dimensions are about the same as those of the injenio. There are two types of circos, one having a crude circular wall 0.6 to 0.7 m. thick, about 1.5 m. high, and 10.8 m. inside

There are two openings in each circo, one for charging the pulp and admitting animals; the other, a small hole near the floor through which the pulp is discharged in the stone trough located in the sluice for washing. The

floor of the circo is well laid with flat stones and plastered carefully with cement to avoid losses in the crevices. In the centre of each circo a low cylindrical stone is fixed to serve as a stand for the mule driver.

The mercury filter has the shape of an acute inverted cone and consists of an upper part, which is made of leather sewed to an iron ring, while the lower part is made of canvas. The filtered mercury drops into a trough made of raw hide and held in a wooden frame below. The illustration on this page represents a retorting furnace, which contains a tripod set in a water-box. The pressed amalgam cakes are placed upon the tripod ; a sheet-iron cylindrical cap (caperuza) is lowered so that its bottom shall be a trifle below the surface of the water in the box ; the furnace is then closed with strong sheet-iron and temporary masonry, and a coal fire is maintained upon the grate for about four hours with a gradually increasing heat until no more mercury is evaporated ; finally, after cooling, the furnace is opened, the retort silver is



A RETORTING FURNACE.

removed, and the mercury is dipped from the tank into flasks. Exceptions to the general arrangement described above are found at a few haciendas.

Interruptions of work in the Cerro are frequent, and mainly due to the lack of water, which is low during three or four months in the year, especially in those mills that are dependent upon the water from the lakes. Freshets sometimes destroy the dams, the replacing of mill stones causes delay, and financial difficulties frequently produce entire suspension of the work in the poorer mills. The mill stones of the plain are of fine hard granite which wears very uniformly. They are obtained from quarries in Cerro Raco, an isolated mountain, about eight miles south of the town. Those of the Puca-Yaco ravine are quarried near the bottom of the ravine and are also ot very hard rock, but develop, in wearing, ridges and hollows in the working-face. These, however, are considered as rather advantageous than otherwise. These large stones are transported by passing a round stick through the centre, fixing it into a rude frame, after which sixteen to twenty oxen are hitched to the frame and the stone is trundled to the mill. A voladera costs about 100 soles at the quarry and 125 soles for transportation.

For milling the ores the sluice of the head-race is opened and the injenio is set in motion, making twelve revolutions per minute. Water is allowed to flow into the lower mill stone, the circumference of which is dammed up a few inches with sods, excepting at a discharge opening. The ore is fed gradually by a laborer and the pulp is carried to the settling tanks by the overflow, from which the slimes pass into other tanks, where they can settle, in order to receive separate treatment subsequently in circos, the losses from the slimes being greater than from the pulp. When one of the tanks is full the water is drawn off and the pulp is allowed to dry a little to facilitate transportation to the circos, which is done in leather sacks. Thirty-five heaps of about equal size are formed in the circo, each heap containing a certain number of sack loads. This is the only method of measuring the contents of the circo, which when charged contains about fifteen tons.

The small pulp heaps are then leveled over the floor, making a tortilla ; about 1000 pounds of salt are added, and eight small horses are driven around in the circle and thoroughly mix up the charge, the driver standing on the elevated central stone. Then 15 to 30 pounds of magistral are scattered on the charge, which is again mixed by the horses ; after that 80 pounds of mercury are finally distributed over the mass, which is again thoroughly mixed. The horses are then introduced and driven in the circo for one and a half to two hours every eight or ten days until at the end of two months amalgamation is completed. In the meantime, however, the charge must be tested carefully by washing small amounts and mercury must be added when the previous charge is absorbed, until finally the total amount added is 230 pounds. If the charge "goes cold" some magistral is added, and if too hot some lime or lime water.

Two months after charging, the entire mass is gradually shoveled into a hemispherical washing trough of about two feet diameter, made of one stone, which is placed in front of the discharge of the circo in the sluice so that one trough serves for two adjacent circos. Water flows into the trough ; an intelligent, strong laborer enters the latter, and with his feet mixes the pulp and water so as to cause the amalgam and mercury to settle. The tailings pass through several troughs, the connecting channels of which are lined with coarse cloth, and through a mercury trap, and are finally discharged, but always require careful testing. There is generally a small loss in amalgam floating off, and in some mills Indians re-wash the tailings by hand, making a small profit. Finally the circo is well cleaned, especially in the crevices, and after all the pulp has been washed and the mercury and amalgam have been cleaned of sand and pebbles, they are

A GROUP OF MINERS.

dipped into raw hides and carried to the filter. The sluices and mercury traps are also cleaned out and their product is added.

The amalgam is then filtered off in a strong canvas filter, which is suspended over a raw-hide mercury trough, the filter being beaten with a flat stick for from one to two hours, to press out all the mercury possible. The amalgam is then taken from the filter and pressed into cylindrical molds of 230 mm. diameter, the height of each separate part being varied according to desire by placing a circular sheet of paper between the consecutive cakes. It is then taken to the retort. Generally, the retort is charged late in the afternoon, fired up with coal for three or four hours and allowed to cool until morning, when the retorted silver is extracted, weighed, marked and taken to the government refinery in town, or sold to the silver merchant, who has the privilege to redistill the retort silver before purchase, to verify its weight. The washing of the pulp, filtering and retorting are generally done about the first of each month, and the refinery is operated for three or four days, beginning on the second or third day ot the month.

In the refinery the retorts are received and weighed ; names and weights are entered in the record, and each lot is kept separate if it is sufficient to make one or more bars of 150 pounds or 300 marcos each ; if not, the owner generally sells the difference directly to a silver merchant. In the refinery the furnace has step grates, and is arranged for two large iron crucibles, holding about 150 pounds of retort each. These crucibles are suspended from cranes in order to facilitate the manipulation. The fuel is a bituminous shale, found near the town and costing 8 soles per ton. It requires about seventy-five to eighty minutes to melt a charge placed in a hot crucible. The melting is watched through small peep-holes in the cover of the furnace, and when it is completed the crucible is extracted with the crane, which catches under two

lugs attached to the outer rim of the crucible. The latter is then set into and tightly gripped by a frame having a vertical toothed quadrant, which is acted upon by a worm-wheel turned by hand, whereby the crucible is gradually brought into a horizontal position, thus pouring the molten silver uniformly into an iron mold set beneath.

Sprouting is prevented by scattering a handful of dry straw in each mold before pouring, and some more straw on top of the silver after it is poured. The crucible is then scraped clean, recharged and set into the furnace. After the silver in the mold has solidified, it is dumped upon an iron plate with the crane, and then pulled into a water trough for cooling, after which it is withdrawn, the rough edges are hammered down, and the bar is weighed, marked and delivered to the owner, together with the scrapings. In melting, a loss fron 2 to 6 marcos is found per bar on its retort weight, mainly due to the mercury contained in it. Each iron crucible will stand about 40 meltings before it becomes useless. A charge of 2 cents per marco must be paid for melting. All the silver produced in the district must pass through the government refinery, and by far the largest part of it is obtained by amalgamation.

Silver-lead smelting is carried on in Cerro de Pasco on a small scale, exclusively in reverberatory furnaces. There are four of these old furnaces in town, but only two or three of them are in intermittent operation. The fuel used is coal, bituminous shale and dried llama-dung. The number of medium sized slag-dumps seems to show that smelting was more flourishing in former times, when the ores were richer. As lead has no commercial value at the Cerro, it is allowed to run into the slag or litharge, and is used again in smelting silicious charges.

A HOLIDAY GATHERING OF NATIVES.

Labor at the mines and mills is almost entirely done by native Indians or peons, and, whenever possible, it is done by contract, so that a man can earn a little more than at day's wages, which average from 50 to 60 cents per day. One of the difficulties with the peons is their great fondness for alcoholic stimulants, which is generally indulged in toward the

end of the week by consuming large quantities of chacta, a liquid distilled from the juice of the sugar-cane. Hence, but little work is done on Fridays and Saturdays. The natural resources of the town, excepting the mines, are very scanty. In the neighborhood good cooking coal and bituminous shale are found. Wood for fuel is brought from the neighboring valleys, while that used for building must be brought from a greater distance. Salt for amalgamation is brought from the great salt-mine San Blas, one day's travel from the Cerro. The price of the salt varies from 1.40 to 2.20 soles per 100 pounds, and, as there is no competition, excepting that of sea salt, which takes from 6 to 7 days to reach the Cerro from the sea port Huacho, the owner of the San Blas mines makes his own prices, and, financially, has all of the Cerro amalgamators under his thumb. As already remarked, the mill-stones of very fine granite are made in the Cerro Raco, 8 miles south of the town, some also being made in the Puca-Yaco ravine. All other articles of convenience or necessity must be brought from the coast with the exception of such as skilled artisans can make from the materials on hand. This exception includes silverware, goods made of leather and the product of spinning and weaving. The Indians make all their own cloth from sheep or alpaca wool, fair articles of leather, and some are skillful silver-workers.

The financial system is very disadvantageous, especially to the poorer mill owners, if they are obliged, as most of them are, to have recourse to the money-lender, who advances money at a high rate of interest, and to whom the amalgamator is obliged to turn over his entire product, receiving 10, 20 and even 30 cents less per marco for his silver. It is not uncommon that some mill owners are constantly in debt, and perhaps finally lose their mills. The present low price of silver must be a great hardship to Cerro de Pasco, which depends almost entirely on that metal for its existence. It is doubtful if any but the very best equipped mills can successfully meet the present conditions, as even in more favorable times many miners and millmen made but a precarious living.

PROPER CONNECTION OF BOILERS AND ENGINES.*

By Theo. F. Scheffler.

TOO much cannot be written about the design or construction of boiler and engine plants, either for electric light stations, or for power plants, or, in fact, for any kind of a power station. Considerable space may be saved by leaving everything to the manufacturers, as well as economy secured in pipe connection. There certainly is a method for setting the engine connected to the boiler so that the best results may be obtained.

For small plants, where there is but one boiler and engine, it is customary to set the engine about 12 feet to 14 feet from the boiler, and put an 8-inch division wall between the boiler and engine rooms, so as to keep all dust accumulating from ashes out of the engine room. For the best results, engines should be set longitudinally with the boiler so that direct pipe connections can be made. This is also, in the writer's opinion, the best method on account of the expansion of the steam pipe. In plants where there are three or four engines to be connected to a battery of boilers, and the engines are placed either directly in the rear, or in the front of the boiler fire room, there will be considerable waste of steam pipe, which will amount to quite an item on account of the steam pipe being large in diameter to accommodate the volume of steam from the boilers to the engine.

For the purpose of having some fixed basis to work from, the writer has taken for an ideal plant the following specifications of boilers and engines, and the necessary items to make a complete and modern steam plant :—

BOILERS.—Four 66-inch × 16-foot horizontal tubular boilers, rated at 100 H. P. each, and to be set in one battery with full arch fronts, and all necessary fittings, such as safety valve, steam gauge and siphon, water gauge with stand-pipe fitted to boiler, three gauge cocks for each boiler, blow-off valve, two check valves, two stop valves for feed pipe, main gate valve for steam outlet, rocking grates, grate bearers, stack plate, rear arch bars, and rear ash door and frame. These fittings go with each boiler. One boiler cleaner for all four boilers.

ENGINES.—Four 13-inch × 12-inch non-condensing, high-speed automatic engines, to develop 90 I. H. P. each ; diameter of steam pipe, 4½ inches ; diameter of exhaust, 5 inches ; diameter of pulley, 54 inches ; face of pulleys, 12½ inches, with complete set of fixtures, such as throttle valve, large size sight feed lubricator, full set of sight feed oil cups, and automatic oiling devices for crank pin and crosshead pin, wrenches, crank shield, cylinder cock drip connection for steam chest, foundation bolts, and one 4½-inch steam separator for each engine ; feed water heater to be 42 inches diameter with 100 2-inch tubes 60 inches long. Engines to set 9 feet, centre to centre and longitudinally with boiler. Pump required for this plant, one 400 H. P. pump, or a pump capable of delivering 3000 gallons per hour, and all necessary pipe connections. Each boiler to have one injector of 100 H. P. capacity, or equivalent to forcing 800 gallons of water per hour into boiler, and all necessary fittings.

In a plant of this size it is customary to use a feed water reservoir tank. Where there is no city water pressure the tank is supplied with water by a pump, the tank being suspended above the boilers, so that the water will flow by gravity to the boiler feed pump,

*Presented before the American Society of Mechanical Engineers.

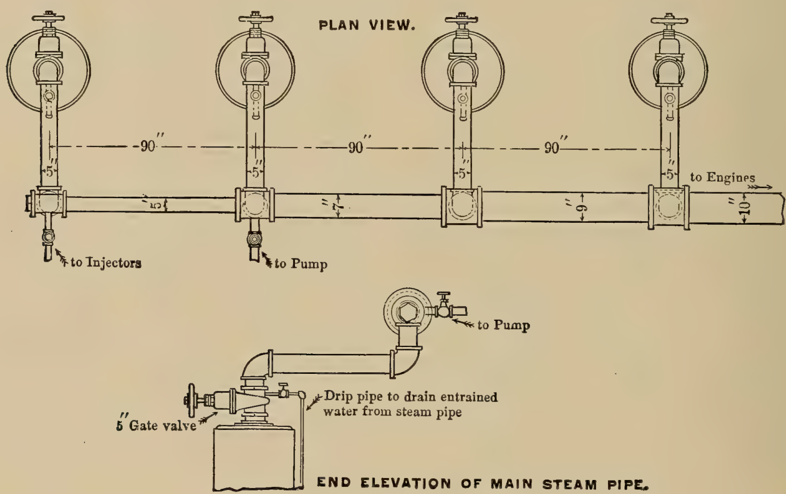
thereby keeping the pump valves flooded with water. One exhaust head should be connected to the main exhaust pipe after leaving the feed water heater.

Probably right here would be the proper place to say a few words in connection with the engine foundations. The depth of engine foundation should be at least 6 feet, unless there is a good rock bottom found before reaching this depth, so that the engine anchor bolts may be anchored directly into the rock ; otherwise, if there is no such rock to anchor to, and the above depth has not been made, there will not be enough weight to the foundation to hold the engine down. The writer is well aware of the fact that there are engines on the market to-day where great care and attention has been given thoroughly to counterbalance the engine, so that the engine will run steadily and smoothly, set upon four pins, and will not jar or shake off the pins, the engine not being bolted to the foundation. The above is all right so far as it goes, but will not answer for large engines, and especially when the engine is very heavily loaded. The length of the foundation on the shaft end of the bed, measured from the centre of the shaft to the end of the foundation, should be equal to the length of the foundation measured from the cylinder end of the bed to the centre of the shaft. The correct proportion for this length of foundation is about seven and one-half times the stroke of the engine.

In a great many cases this length of foundation on the shaft end of bed has been very much diminished. There is no better place to throw in brick on an engine foundation than on the shaft end; here is where the weight is required.

The above dimensions which have been given will make the ends of the foundation equally divided on each side of the centre line of the shaft, making the centre of the shaft in the centre of the apex of the foundation. The width of the foundation at the bottom should be equal to eight strokes of the engine. In this case, the stroke of the engine is 12 inches, multiplied by 8 inches, which would equal 96 inches. The number of brick which would be required for this foundation is 7500.

Having found the proper dimensions of the engine foundations, it will be as well to give thought to the relative proportions of the boiler foundation and settings. The writer has found by experience that 3 feet deep will be sufficient for this size of boiler, below the



FIGS. 1 AND 2.

floor line. A good, hard sand stone will give good results when brick is not used, which some people prefer. The width of the foundation should be 6 inches more on the floor line than the boiler side walls, which, in this case, should be 24 inches wide. There has been considerable argument about the best height from the floor line to the fire door opening ; 22 to 24 inches is a very satisfactory height, but 30 inches is considered much more satisfactory and better adapted to the ordinary fireman. This height has been obtained for these boilers by raising the bottom of the fire fronts 6 inches above the floor line, as the height of opening is but 24 inches in the casting. This method of raising the front has proved very satisfactory wherever it has been adopted. Another point to be considered on these boilers, is the height from the top of the bridge wall to the under side of the boiler shell. The height in this case is 12 inches, and this gives an area between the top of the bridge wall and the bottom side of the boiler shell of 1550 square inches, which is equivalent to double the area of the boiler tubes. For the best results in combustion and efficiency, this height has proved to be very satisfactory. The bridge wall should be made horizontal on top. Some manufacturers recommend the top of the bridge wall to follow the curve of the under side of the boiler shell with the necessary area between the bridge wall and the boiler. Another good point for consideration is the distance from the top of the grates to the bottom of the boiler shell ; in this particular case it is 26 inches. This height has proved to be very satisfactory. Of course, there is a wide range of opinion on the height ; some manufacturers prefer but 23 to 28 inches and some even prefer 30 inches. The writer has found this height to suit in almost every possible case. The height given is about the average, and will evaporate more water than if the height was 30 inches.

The boilers and engines having been set up on their foundations, the next point in view to consider, is the main steam pipe and fittings. We will first consider the correct diameter of the main steam pipe. As we have in this case four steam outlets from the four boilers, one from each of the boilers, and, as the commercial diameter of each pipe is 5 inches, we shall require a main steam pipe with an area equal to four times the area of the 5-inch pipe. The area of a 5-inch pipe is 19.63 square

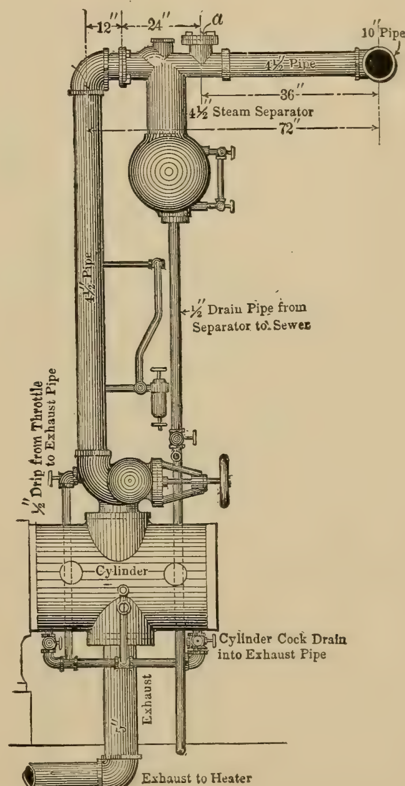


FIG. 3.

inches. This multiplied by 4 gives 78.52, which is equivalent to a pipe 10 inches in diameter. The pipe is constructed on the telescopic method, that is, the diameter of the pipe from the first boiler to the second boiler is 5 inches ; from second boiler to third boiler, 7 inches ; from third boiler to fourth and last boiler, 9 inches ; and from the last boiler to the engines, the diameter is 10 inches. This pipe will carry all the steam which the four boilers can supply, and with a minimum

resistance. Observing the end elevation, Fig. 2, the main steam pipe is at the extreme height. This arrangement

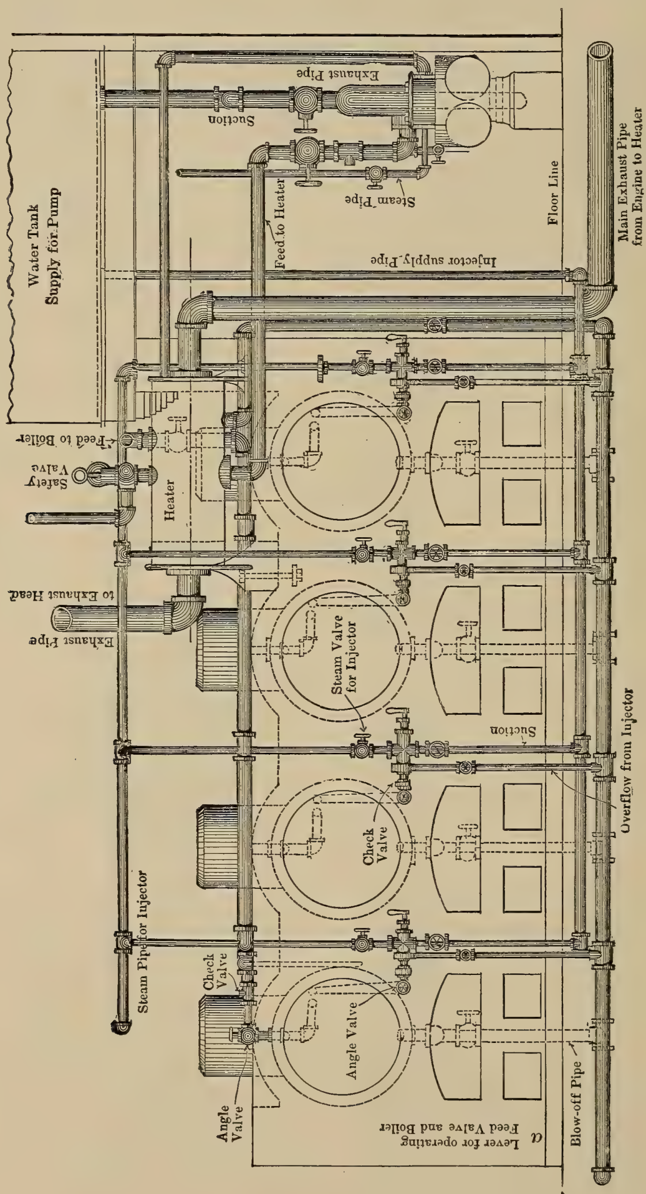


FIG. 4. END ELEVATION.

allows of all condensed water flowing back toward the boilers.

There should be a drip connection placed on the gate valve just above the valve seat, so that condensed water may be drained off. By this arrangement of drip pipe, considerable water may be saved from getting into the engines. It will also prove to be economical and saving of steam from the boiler after the gate valve is opened; for, if this accumulating water is not let out at the boiler after any one of them has been

shut down, the steam will condense very rapidly. Of course, this is only a small saving of steam.

The main steam pipe is located 36 inches from the centre of the dome. This is done so that when the steam pipe expands or contracts, it will not make any strain on the screwed connection at the point marked A, but will naturally swing from the centre of the dome, the centre of the dome becoming the fulcrum of the main steam pipe. The steam pipe connection for the engines are made in the following manner: First, a short piece of 4½-inch pipe is connected to the main steam pipe and then to the steam sepa-

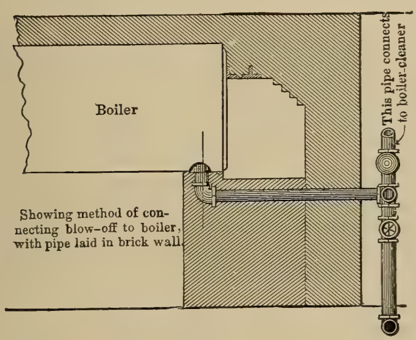


FIG. 5.

rator (Fig. 3). The steam taking a spiral course inside the separator, causes the water to be thrown by centrifugal force against the outer walls, while the dry steam goes through the small holes to the centre of the pipe. When it is not convenient to pipe up the separator as shown, steam may be taken into the separator at *a*.

The separator should be located as close as possible to the engine, so that nothing but clean, dry steam will be supplied to the engine. The main steam pipe is located 72 inches from the 4½-inch vertical steam pipe, which is connected directly to the engine throttle valve. This allows the 4½-inch horizontal steam pipe connected to the separator to swing from the elbow B when expansion or contraction takes place. Fig. 3 also shows the exhaust pipe connected to the cylinder. The continuation of the exhaust pipe, connected to the feed water heater, is shown in Fig. 4.

The best and usually the most convenient place to locate a feed water heater is on top of the boiler side walls, placed at right angles to the boiler and set horizontally, the heater being supported at each end by a cast-iron leg or bracket, and each bracket anchored into the boiler side walls by anchor bolts.

This method of locating the heater has been, as described above, placed on several large boiler settings which the writer has designed. Any person who is in any way familiar with boiler settings knows how hot it is over the top of boilers, and can readily see the advantage of locating the feed water heater above the boilers. From 5° to 10° of additional heat will thus be obtained for the feed water over that supplied, if the heater is set up, as in common practice. To set the heater on top of the boiler will cost a little more, but it will soon pay for itself by being economical.

The injector should have a separate feed water pipe, on entering the boiler, so that in case any accident should happen to the pump pipe connections, or repairs should have to be made on the pump or to any of the connections, there will be no loss of time by having to draw off the steam from any of the boilers, in order to make the necessary repairs. If necessary, by closing the main feed water pipe valve connected to the pump line of pipe, after the water is forced through the heater, and by closing the feed pipe valve over each boiler, the whole line of pump pipe connections may be disconnected, and the boilers fed with the injectors. A check valve should be placed over each boiler for the feed pipe, and also between the pump and heater. This will keep all pressure away from the pump and will be beneficial in case anything should happen to the boiler checks. The blow-off from the heater is connected to the main blow-off pipe, as well as the overflow from the injectors, and the discharge may be con-

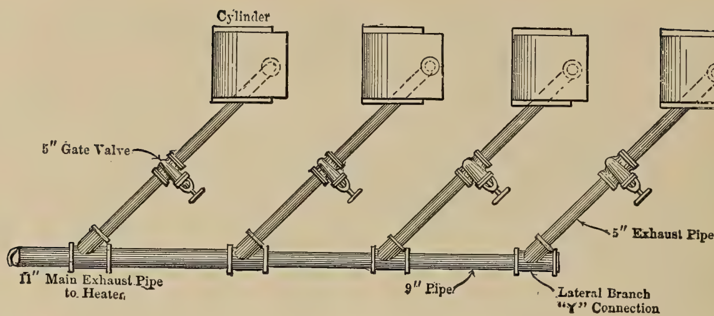


FIG. 6.

nected to any convenient point which will be the nearest at hand, or may be carried to the sewer. To operate the blow-off on the boiler or heater, the globe valve on the injector pipe should be closed. The injectors are supplied with water from the water tanks overhead; this will give a constant supply of water under a head of water at the injector.

The main steam supply is connected to the main line of steam pipe leading to the engines. The idea of doing this, is in case anything should happen so that any one or two of the boilers should be off duty, the supply of steam would be constant, in taking steam from the main line of steam pipe. A good way to connect the blow-off pipe to the bottom of the boiler shell and keep the pipe intact from burning out, is to build a small wall of fire-brick, about 9 inches thick, and lay the pipe in the centre of the brick. This wall will not diminish the area of the combustion chamber enough to destroy any of the draught. The pipe connected to the boiler is shown in Fig. 5.

The exhaust pipes leading from the engines to the main exhaust pipe should be constructed so that there would be a minimum amount of back-pressure. To do this satisfactorily and with the best results, a lateral branch "Y" connection should be made where the pipe meets the main exhaust pipe. (See Fig. 6). A valve should be placed on the pipe leading to the main exhaust pipe, so that in case any one of the engines is stopped for repairs, the exhaust steam from the other engines would not back up into the steam chest, in case the valve on the engine was disconnected from the engine. The

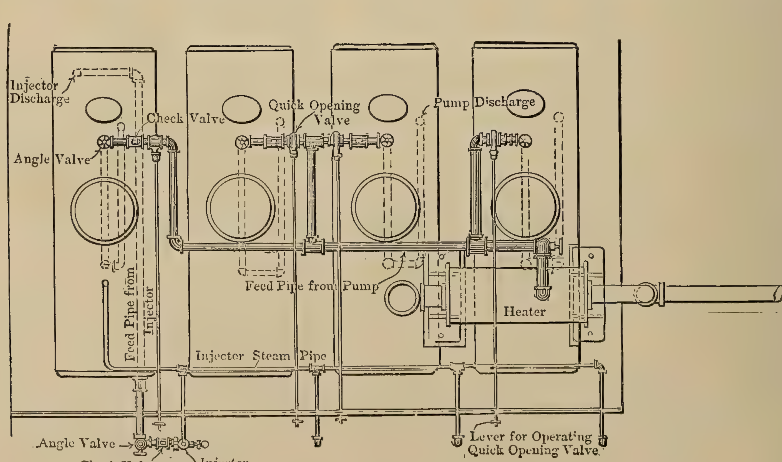


FIG. 7.

"Y" connection also does away with the short and sharp angle connection and makes a freer passage for the steam.

Referring to Fig. 7, we have a plan view of the pump feed pipe connections with fittings, also the injector connected to the boiler. It will be observed that the injector pipe runs nearly the whole

Showing arrangement for connecting Boiler Cleaner to Boiler

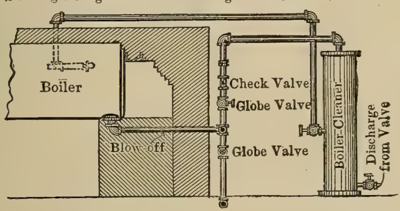


FIG. 8.

length of the boiler and toward the rear before discharging the water directly into the boiler. The advantage of this is apparent. The feed water becomes well heated before discharging into the boiler, and its chilling action on the shell is greatly lessened. There has been considerable discussion about where the feed water should enter the boiler, and the writer believes that this method is freer from objection than any other which could be selected. The pump feed enters the boiler at one-quarter of the whole length of boiler, at the rear, and the pipe is kept as close as possible to the boiler shell, so that there will be room enough for a man between the pipe and the top of the tubes. The pipe then continues ahead about eight feet and then turns toward the boiler shell on the side, and then turns and comes back where it started from and discharges downward. Some persons may say there are too many turns employed in this method, but the feed pipe is made much larger after it enters the boiler to reduce the resistance caused by friction to a minimum. Fig. 7 also shows a plan of the feed water heater.

Figures 8 and 9 illustrate the method for connecting the boiler cleaner to the four boilers. The reservoir for receiving all of the sediment collected from the boilers is located centrally between the four boilers, in the rear. The action of the boiler cleaner is here described. As the water boils and circulates toward the top and rear of the boiler, the scoops gather all sediment which rises to the surface of the water and is then discharged by the boiler pressure into the reservoir. The water and steam may be let out of the boiler, independent of the boiler cleaner when it is necessary, by closing the valve connected to the boiler cleaner and opening the valve connected to the blow-off pipe proper. There is a globe valve attached to the bottom of the reservoir, where the sediment which has collected may be let out. This sediment should be let out every other day.

The writer desires to say, in conclusion, that about twenty plants have been connected up as described in this article, although they have not all had boiler cleaners, nor has the injector been connected separately to the boiler, and the engines and boilers were arranged somewhat differently in the set-

Plan of Boiler Cleaner

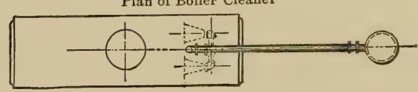
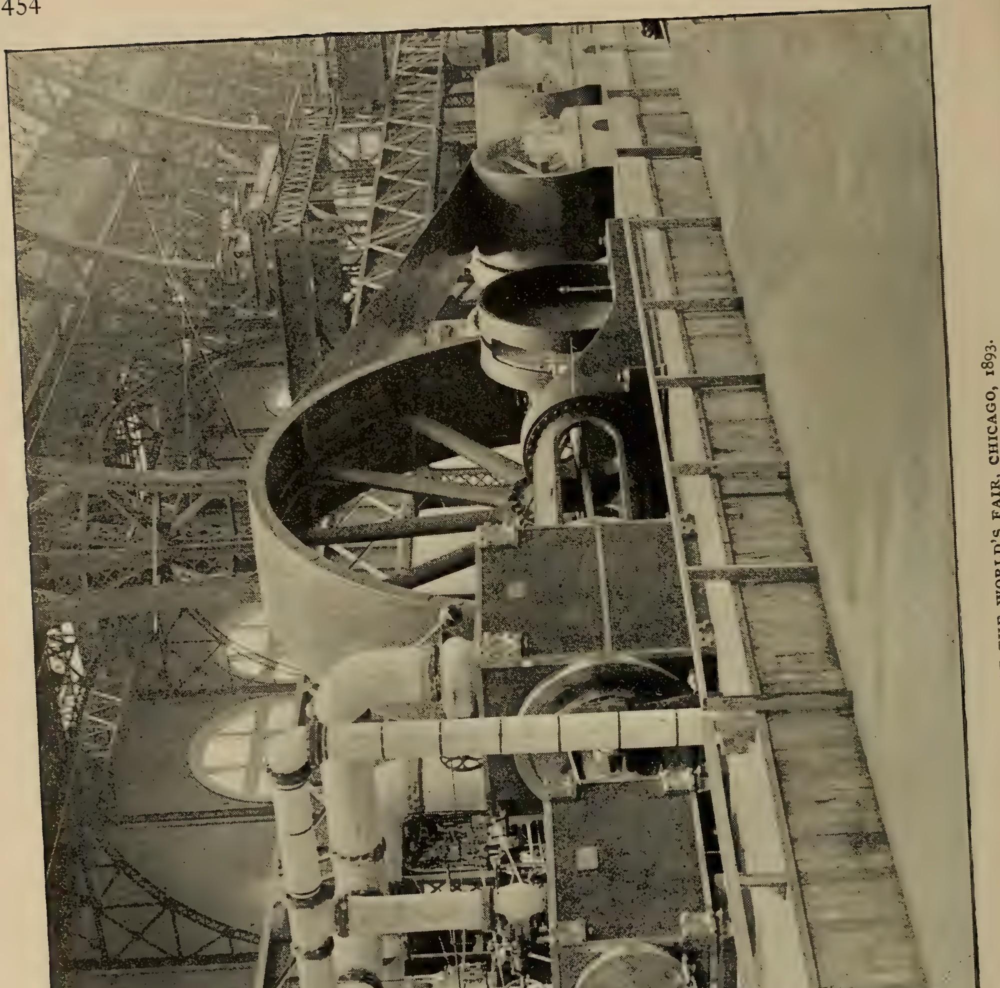


FIG. 9.

ting; but all are giving good satisfaction, and the piping in general was arranged as described here. Further, in regard to piping in general, in case of any accident to any part of the plant, the part which is crippled may be shut off without shutting down the whole plant. The steam will reach the engine with but little drop in pressure, as all pipes are covered with an asbestos air space covering.



THE ALLIS-CORLISS 3000 HORSE-POWER ENGINE AT THE WORLD'S FAIR, CHICAGO, 1893.

THE EVOLUTION OF THE MODERN STEAM ENGINE.

By John E. Sweet.

THE following thoughts called up by a discussion of the evolution of the modern steam engine by members of the American Society of Mechanical Engineers were, in the main, given in a paper at one of the monthly meetings of that society, but, owing to a hasty preparation, the original has been somewhat modified, corrected and extended. The drift of the discussion tended in the direction of a consideration of the engines exhibited at Chicago and at other world fairs, an examination of which the author had only such opportunities for observation as visitors in general.

Reviewing the past, the writer would go back to the first step in the stairway of his interest in steam engineering, the exhibition of the Royal Agricultural Society, at Battersea Park, at London, in 1862, or 31 years before the Columbian Exhibition at Chicago. Remembering that there were many portable engines there, and turning back to letters written home at that time, the author finds this paragraph: "But one still greater feature than all was the almost incredible number of portable steam engines, 83 different ones, all with steam up and going at the same time, and driving threshing machines, straw cutters, grist mills, tile and brick machines, etc. Six or seven were traction engines."

To this might be added something about steam plowing, which was then and still is successfully practiced in England, and the steam road rollers, which were common. This subject is not called up to show how Americans outstrip all other nations (in following in their footsteps), but to call attention to this branch of steam engineering, which has not been thus far considered, and to describe one of the many things which the writer saw at Chicago, and which excited his liveliest admiration.

A traction engine of not the largest size, built somewhere in Ohio, well invented, not very well designed, frivolous in some of its details, and deplorable in workmanship, was harnessed to a 5-ton load of pig iron piled on a stone boat. The engine hauled that around over the dry ground with as much indifference as if it had been so many sticks of wood. It went down into the canal, wallowed around like a sea lion, and out up a bank where one would not expect to see a team draw up a wagon. It was driven up to a railroad track where the ties had been blocked up until the top of the rails were 2 feet above the level. The engine mounted this obstruction diagonally, first one forward wheel, then the other; then alternately the back wheels in like manner, running along over the ties and turning off diagonally as it had mounted, in fact, performing the feat precisely as an elephant would have done, and with like ease and indifference. The whole show was a comedy in mechanics.

The writer was so astounded at this exhibition, so elated to see the justifiable pride shine out of the builder's countenance, that he did not stop to consider then, as he hesitates to question now, whether it would not have been better to build the engine with less of the spirit of a gymnast and more in line of durability in its legitimate work. Allowing the thing to be worth doing, the man who did it is never

likely to receive half the credit he deserves. When the conditions are considered and the means are compared with the end, the builders of stationary engines and locomotives may take off their hats to the builders of traction engines.

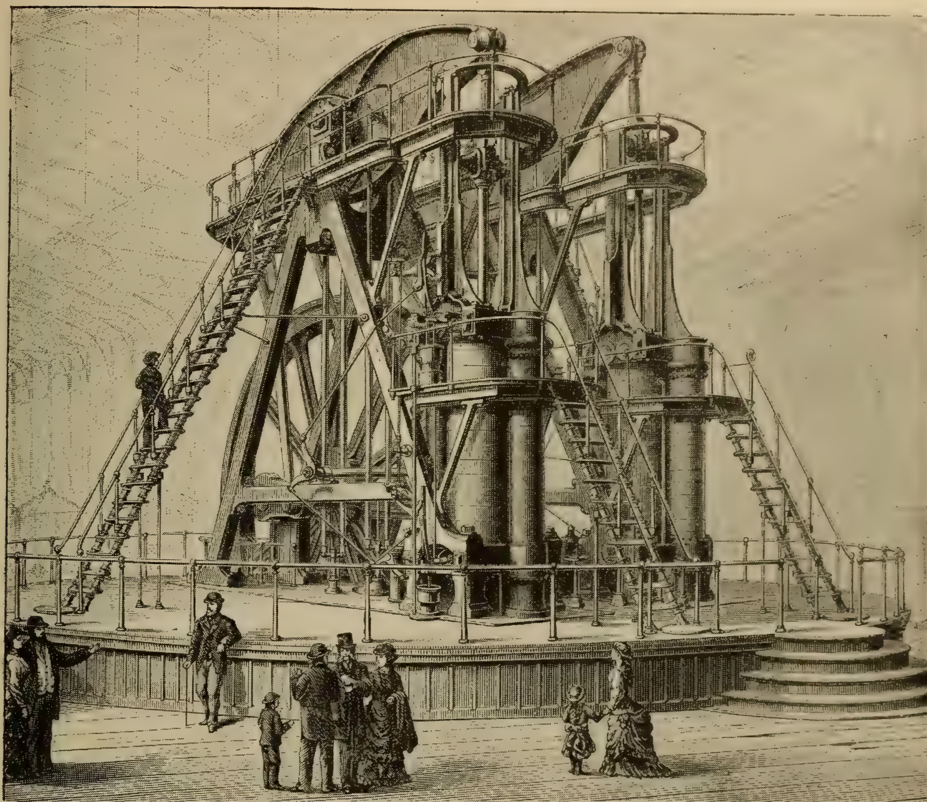
As the Cornish pumping engine set the pace in steam economy for half a century, so the Cardiff trial of portable engines twenty years ago set the mark so high that small engines of no kind have as yet in the United States approached it. Compound portables have long been common in England, though they have not yet appeared in America to any great extent.

To go back to the same year, 1862, the year of the second London Exhibition, the writer's memory does not even picture the steam engine exhibit, but he remembers that Mr. Porter exhibited a rapid-running engine, and patented, introduced and promoted the manufacture of the Richards indicator. There is called to mind one or more complete marine engines, for war ships probably, of a form long ago abandoned, but which certainly showed designing of a high order. There were horizontal cylinders, placed one on each side of the screw shaft, close to and level with it, but one forward of the other so as to work on the two cranks set at 90 degrees as at present. Each piston had two piston rods set diagonally, one over the shaft and one under it, and far enough apart to admit the shaft crank between. The crosshead and guides being on the opposite side of the shaft from the cylinder, the connecting rod worked the other end too, that is, the crank box passed as close to the cylinder head as possible. For a compact low-down arrangement this would be difficult to improve.

The next step on the Exhibition ladder was the Paris Exposition of 1867. At that exhibition two engines of mark beyond all others set their hands upon the industrial world, and have held them there for a generation—the Corliss engine from the parent works at Providence and the Porter-Allen built by Whitworth. While the Porter-Allen was admired, and the maker's name demanded respect, it was too novel, untried, or for some reason did not take root in Europe. The Corliss engine, new to the Continent, was admired for its silver jacket, polished bonnets and general trousseau, ridiculed for its complexity, but understood by the leading engineers of Europe. It was taken up by several leading firms, and is to-day one of the standard engines of the world.

While the natural sons of neither of these engines (the Corliss and the Porter-Allen) were shown at Chicago, what has been designated the Hyphen-Corliss, and what may be styled the Fitz-porter engines, constituted the bulk of that wonderful collection in Machinery Hall. It may be true, and likely is, that there were high-speed engines built before the Porter-Allen engine, but it is one that still lives, and one that probably has suffered least by changes and modifications, certainly least of any in looks.

Mounting the third step of our experience, we come to the Centennial Exhibition. While compound engines were quite common in Europe and on the sea, and Adamson had built his quadruple engine, only one was shown at Philadelphia, in fact, American engineers did not believe in them. A compound engine designed by John H. Cooper was shown, but it was ahead of its time, though one on the same general plan was soon after erected at the works of Russell, Birdsall & Ward at Port Chester and is still in use. The engine has shown an economy about equal to any of recent construction. Although the single cylinder engine has been transformed into many shapes, it had then reached a pretty high state of completeness; the Buckeye, the only engine shown at both Chicago and Philadelphia, the Wheelock, the Brown and the Corliss had reached the forms which they followed for many years. The Corliss centre piece, with its two single cylinders, walking beam and 30-foot gear, was one of the grandest steam engine monuments in its impressiveness ever erected at an exhibition, but judged in the light of present practice showed,



THE CORLISS ENGINE AT THE CENTENNIAL EXPOSITION, PHILADELPHIA, 1876.

as Mr. Porter pointed out at the time, just "how not to do it." In explanation of this statement it may be well to give the substance of a friendly criticism of the great Corliss triumph, held under its own shadow.

It was a beam engine with two 40-inch cylinders, 10-foot stroke, two walking beams coupled to the two cranks of a shaft carrying a 30-foot gear working into a pinion some 12 feet in diameter, the engine making from 35 to 38 turns, and the second shaft about 90. By what process of reasoning the conclusions were arrived at is not now remembered, but it was agreed that two 40-inch cylinders at 4-foot stroke, directly connected to the second shaft and run at the same piston speed, would accomplish the result at an immensely less expense. The whole Chicago display showed that this is what would now be done, and while it has been allowed that there has been a gain in pumping engines of only from 20 to 25 per cent., it is likely that the Allis Chicago engine will harvest 2 horse-power from the sowing of the same amount of coal that it would take to get one from the Corliss Centennial, which, as it was specially suited to compounding, and yet was not compound, shows that Mr. Corliss, at that time, had not been convinced that there was enough advantage to go to that slight additional expense.

The writer is well aware that it is almost sacrilegious to criticise the design of that wonderful Centennial monument, but will do so in the belief that the very audacity of the thing will emphasize the point which he wishes to make. The design was in two distinct styles intermingled, just the wrong thing to do as well in machinery as in a build-

ing. The framing was of the most severe straight lines, almost seeming to be simply a reproduction in iron of its wooden prototype, while the beams were in graceful curves, and the lever arms of the valve motions not curves but crooked and fairly graceful. Milan Cathedral and the Corliss engine are noble examples of mixed architecture, but noble in spite of the mixture and not because of it. There is this to be said, however, in defense of the Corliss engine, the design was consistant in this, that the stationary parts followed one style and the moving parts another.

When one sets himself the task of looking into this feature of machine design he will find in it one of the explanations of why things do not look right. There is an engine of recent production where the arms of the wheels are elliptical, a conspicuous lever of I section, rocker arms round, cylinder head one style and steam chest covers another, and yet there seems to be no apparent reason why, if the machine had been consistently designed, it would not accomplish the work just as well as it does now. The writer was well aware of the danger encountered in criticising designs, and to simply say one looks well and another not, without giving the reason, is setting one man's opinion against another ; but certainly there is such a thing as consistency, which plainly is subject to demonstration.

Builders of the modern improved Jones, Smith & Brown Corliss engines found themselves confronted by a new condition. Steam pressure had gone from 60 to 120 pounds, and something had to be done to resist the extra strain. Three methods were open to them—put in more iron, put it in a better form, or make more attachments to the foundation. As is usual with improvers, most of them took the wrong road. Hicks & Hargraves of Bolton, England, adopted the right plan on the start by making the frame a complete box. The only Hyphen-Corliss engine exhibited at Paris in 1867 was of this make and this form. At Chicago two of the Corliss type claimed to be box section, but the builders spent some money to spoil them by cutting ornamental holes through their vital parts.

A round column, not more than 24 diameters in length, cannot be improved, except by putting more metal in it. In any other form it can be by making it round. A round tube is not a suitable form for an engine bed; a rectangular one is, and is nearly as strong as a round one. Aside from the push and pull, the strain on a Corliss bed is a bending and torsional one. A rectangular box will resist these strains about 16 times better than I-beam of the same cross section. Against a push and pull strain a crooked element is a weak one. If it must be crooked, a box section is best able to resist it, but why crooked? There is plenty of room around a Corliss engine to make a bed straight and have it right, and when it is right it will look right, provided the designer has the ability and the observer the right training. This in no way means that everything should be straight, for as often, perhaps more often, the thing to be right has to be the furthest possible from that, and the one who makes that thing straight that should be crooked makes a worse blunder than the other. Whoever is father of the straight-line feature in machine design will have many occasions to be ashamed of his children.

As mentioned before, if there are two roads for an imitator to take to improve an original design he will take the wrong one ; so, too, if there is any one feature that is bad or less meritorious than another, he is sure to stick to and accentuate that with a persistency worthy of the best, and mutilate the subtle beauties which he cannot appreciate, and this confirms one in the notion always entertained, that the overhanging cylinder of the Porter-Allen engine is not altogether right.

Of the dozen or two of engine builders, both those who allow that their engine beds are of the Porter-Allen type, and those who build the same thing without the allowance, adhere persistently to the overhanging cylinder, and remodel the graceful contour of the bed, which has never been equaled, with a freedom wonderful to behold. They not

only adhere to the overhanging cylinder, but attach another and set up a prop as a support.

The writer does not underestimate the animosity that he is likely to excite by criticising designs, and offers the following in justification, not in justification as to the right and wrong of his opinions, but in justification of doing the thing at all. We, all of us, talk about each other's plans, whether cross-compound, tandem, horizontal, upright, triple-expansion or valve gear, without any feeling in the matter whatever, and steam engineering has been immensely benefited thereby.

Artists, the most jealous of all people excepting musicians, criticise each other's work, and submit to the irrevocable decision of a hanging committee, and how are we to improve our designs better than to submit to the condemnation of our bad work by others, and applaud the good in others? It seems as if the question of whether cabinet work is an appropriate adjunct to a steam engine or not could have but one answer, and still it goes on, looks well to most people when new, and horrid to everybody ever after. It would seem, after the example set by the Reynolds-Corliss, the Buckeye and the German engines at Chicago, that we would soon see the last of it. At the Paris Expositions of 1878 and 1889 the Corliss and the Wheelock engines occupied conspicuous positions, and at the latter the Brown, the Armington & Sims and the Straight-line were shown in the American sections. All, however, were single-cylinder horizontals among a grand display of compounds, a magnificent example of Corliss from Creusot and a highly finished engine by some other French company.

This leads us to the final step, the Columbian Exposition. Through the kindness of the various builders the writer was able to get a pretty accurate statement of the number, size, kind and power of the various engines of about 100 horse-power and upward. The list does not comprise the small engines, of which, perhaps, there was 150 horse-power all told, nor does it include pumping, air compressing, gas engines and portable or semi-portable, of which no guess even has been made. There were 29 single-cylinder engines aggregating 4820 horse-power; 47 compound engines aggregating 24,930 horse-power; 5 triple expansion engines, aggregating 3925 horse-power; and 1 quadruple engine of 3000 horse-power, making, in all, 82 engines of a total of 36,675 horse-power, exceeding the Campania by 7000 horse-power, making it possibly the greatest aggregation of steam power ever assembled in so small a space.

Comparing the work of the present with that of 17 years ago, the Centennial with the Columbian, Chicago with Philadelphia, so far as the use of the steam engine is considered, it is a change from single cylinder to compound, triple and quadruple expansion, and the generation and development of the single balance valve, shaft governor, high-speed engine. But so far as the production of steam from the combustion of coal is concerned, the best of to-day is but little better, if any, than the best of 1876, nor is the average to any great extent better than then. Boilers have been improved, so that high pressures are as safe to-day as the lower pressures were before, and as more power is obtainable from high pressures than from low, the modern boiler contributed to this extent its share to the improved economy. Water-tube boilers were wholly employed at Chicago, but that is no gauge as to what is the practice of the country, and only indicates the tendency which points as much toward higher pressures as it does toward the water-tube varieties, and the water-tube is gaining because of its ability to carry the high pressures.

An incredible amount of work has been expended on boiler and engine-room auxiliaries, some of unquestionable and much of questionable merit. Nothing has come to replace the Worthington duplex steam pump, as its many copies confirm, wasteful as it is said to be in steam economy; and the various forms of steam injectors are mostly modifications of the original, and they

hold about the same relation to the steam pump as they have for years. There are many new and many modifications of both single-acting and duplex pumps, and many modifications of the injector, mostly double, using the principle of the inspirator, but the main improvements have been in the simplifying of the number of handles to be operated, and in the devices that make the injector self-starting. Economy in the use of steam, either in the steam pump or injector, does not appear to have made much headway ; at least, the more economical have not swept the old aside to such an extent as the automatic engine has superseded the slide-valve throttling sort.

Boiler feed heaters have taken on new forms, with likely constructive and, possibly, with operative advantages, but with little strikingly new in principle, otherwise than where heaters and filters are so combined as to better rid the feed water of its impurities before entering the boilers. Treating the water with chemicals and filtering is probably the most recent and advanced change that has been made. Various new boiler compounds have been compounded, but what advance, if any, has been made is in a wider understanding that the remedy must fit the disease? Just so far as compounds or filters prevent incrustation, or contribute to keeping the boilers clean, just so much they have contributed to economy, and if all fixtures are credited with the saving claimed, they far more than make up for the increased boiler efficiency, so that boiler makers may be falling back rather than progressing in the economy of steam production, though that is not likely.

Automatic damper regulators, high and low-water alarms, sediment pans, automatic boiler feeders, improved grate bars, mechanical stokers, various steam and oil separators, and the steam loop—a wonder in its way—have been studied over, changed, improved, perfected, or invented and applied during recent years, and these, too, in their way, have contributed to steam economy ; but in none has the change been more marked or results so advantageous as in the engines themselves.

Considering the engine exhibits at Chicago in the order of their magnitude, the 7700 horse-power of Westinghouse, Church, Kerr & Co. was so far beyond anything ever before shown by one exhibitor as to set aside comparison. Their standard and compound engines, which have been on the market for a decade, call for no comment except that inspired by the wonderful growth of the industry. To install an experimental engine at an exhibition is a very risky thing to do ; to install six experimental 1000 horse-power engines of entirely new design, embracing untried mechanical devices, was a courageous one, and one that entitles the company to as liberal consideration as the result requires to make the account stand on the creditable side. The new feature of an air spring to balance the weight of valve mechanism, and at the same time to serve as a starting gear, was as good a scheme as the many other good schemes shown by other makers.

The 3000 quadruple Allis was almost too large for one's comprehension, and the writer hesitates about raising the question whether the addition of the new feature to prolong the cut-off, and thus increase the range of power, is the best way to accomplish the result. The Willans experiments tend to show, so far as an experiment with that style and that size of engine can determine, that the superiority of automatic cut-off over throttling is less conspicuous on a compound than on a single cylinder engine, and shows that it is of very little or no economy at all in a triple expansion. If this applies to all multiple-cylinder engines, then it may be possible that it is the best plan to reduce the valve motion to the simple elements, and govern by a throttling governor. If this will hold good in the case of the Allis engine, of course the same points come up in the Buckeye, Fraser & Chalmers and others, showing novel motions, whose aim is in the same direction. There is this, however,—any amount of complication is justifi-

able in a large engine if one gets the results.

There is more or less tendency to mix the shaft governor and Corliss valve, as was shown by three or four different examples, the aim being to retain the good points of the Corliss valve, to obtain a later cut-off, and to be able to run at higher speed—a promising scheme. One word about the Bates drop motion. If it is as good as the detachable arrangement, then the builders can pride themselves on having something of their own, and while it does not place them above the first step on the Corliss monument, it puts them one step above those who only follow the original. The writer cannot follow out the list, noting every improvement that each engine builder claimed, many good, perhaps one as good as another, and all worthy of a more extended notice than space will permit.

Among the marked novelties in engines—that is, a complete engine, that by Dr. Laval, of Sweden, was one of the most conspicuous. The writer being himself the grand-nephew of a rotary engine, and this being a rotary engine, he speaks as a relative, and ventures to predict that, notwithstanding the 10,000 American patented rotary engines, this little Swedish bumble bee of a thing is nearer seeing the daylight of success than any other before exhibited. While it employs the principle of a Pelton water wheel it possesses just those additional elements not in the Pelton wheel that make it a promising advance.

The Willans engine, while nearly as old as many well-known American engines, is new to American engineers, and remarkable in many respects, but particularly for its economy in spite of what have been supposed to be detrimental features, throttling, single-acting, mechanically fitted valves and high speed. But these defects, whether imaginary or real, are overcome or neutralized, and other advantages come in naturally, so that while at first sight the claims for its economy are questioned, there is a lot of genuine steam engineering in it. Besides the low clearance, free escape for water, and no loss from compression, the main thing lies, it is believed, in the fact that the steam end of neither cylinder is ever in communication with the one of lower pressure or with the condenser. The enormous growth of the Westinghouse engine has been mentioned ; that of the Willans has been phenomenal—20,000 horse-power last year. Americans are prone to joke over the slow, conservative English, but some things seem to flourish in England as well as in the United States.

For great power in small space—the claim which Americans make for their high-speed engines—it seemed about an even send-off between the Westinghouse, Willans, and that crowning feature of the Chicago engine display, the triple expansion 1200 horse-power in the German exhibit. Personally the writer has but little to say about this engine, though he went by it several times a day for three months. It was never his good fortune to be there when they were making repairs, and so he could see no more than other visitors. Another engine of like power, and occupying much more space and far more pretentious, seemed to be in a chronic state of repair.

The Creusot engine was not only by far the best piece of machine work that the writer ever saw, but up to the present time he believes it would be utterly impossible to produce the like in the United States, and for the same reason that they could not there produce work like the "Venus de Medici" or Raphael's "Transfiguration."

As shown by the exhibits at Chicago, the standing appears in this way : The largest and most economical, and probably as economical as has been thus far at an exhibition, was the Allis engine ; the largest exhibit by any one firm was that of the Westinghouse, both American ; the most economical high-speed engine, the Willans, English ; the best piece of steam engineering, considering both design and workmanship, the German ; the best rotary, Sweden, and the best workmanship, French.

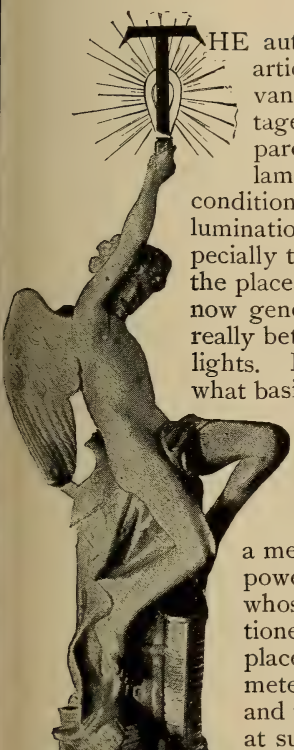
As to the future, the writer suggests looking forward to using better judgment as to putting the right engine in the right place. There is a right and wrong place, if not for all, at least for several kinds of engines. The claims against the high speed are that it is not economical, and terribly prone to smash-ups—claims pretty well founded; but, in spite of that, it has built itself up, and was the means of building up the largest half of the electric light business. As to its wasteful use of steam, that has been overestimated, and is fast being improved; and as to the smash-ups, better separators and safety devices, and the destructive fly-wheel accidents of the last two years of slow-speed engines makes it doubtful, when counting delays, whether the cost of breakdowns in the high-speed engines equals that of the slow. With the high-speed engine and Mr. Porter came better work, and much better yet is needed, and will be demanded, for there is a place for the high-speed simple engine that nothing else can fill. There is, too, a place for the Corliss engine, and a place for the compound, though already many of them have been put in the wrong place; there is a place, and as yet a good deal of unoccupied space, for a vertical direct-connected machine, and places for the triple and, possibly, quadruple-expansion engines. There is an opening for better designs, a field for better workmanship, especially in castings; and as to the opportunity for improvement in steam engineering, as it has been, so it will continue to be.

While it is practically impossible for a compound or multiple cylinder engine to work economically through so wide a range of power as the single cylinder engine, much can be done if the arrangement of governor has control over the various cylinders, making a proper compromise between controlling the cut-off in the high pressure only and the same cut-off in all cylinders. The writer devised a plan several years ago embodying the following notion applicable to compounds, and consisting of one fixed eccentric driving both valves a mean distance, and a second eccentric, controlled by the governor, to add to, or subtract from, the motion given by the fixed eccentric, and unequally for the two cylinders, and it seems that, as this would call upon the governor for but about three-eighths of the power required to drive both valves, the arrangement ought, for the shaft governor variety, to be a good plan.

As a wonderful change has come over the spirit of intercourse between the various engineers and engine builders during the last ten years, so too it is to be hoped—in fact, it may be confidently expected—that a change will come over the method of selling. The many new builders entering the field, and the rush for business led to the desire to secure the influence and trade of the electric companies until it reached a point only a shade this side of blackmail or a boycott. What with advertising, agents' fees, commissions and the buying up of some one's good will, it costs as much to sell some engines as to build them, and it is to be hoped that the depression in trade will blot out this rotten state of affairs if no other good comes of it. This may be thought to be the commercial part of the business and out of place in an engineering article; but when the selling end of an engine business assumes to be the large end, then there is not much hope for engineering triumphs.

INCANDESCENT VERSUS ARC LIGHTING.

By Prof. W. A. Anthony.



THE author proposes in this article to discuss the advantages and disadvantages of the arc as compared with incandescent lamps under the various conditions where artificial illumination is required, but especially to consider whether, in the places where arc lamps are now generally used, they are really better than incandescent lights. Let us first consider on what basis the comparison of the illuminating powers of the two sources should be made. Incandescent lamps are now "volted" for a mean horizontal candle-power; that is, a lamp whose filament is proportioned for 16 candles is placed upon the photometer with its axis vertical and the plane of the loop at such an angle with the photometer bar as has been found by previous tests of the same class of lamps to give a measurement equal to the mean horizontal candle-power. The voltage is then adjusted until the photometer reading is 16 candles, and the voltmeter reading is marked on the lamp.

As lamp filaments are now made, the illumination on the horizontal plane at various angles with the plane of the filament varies but little. In the vertical plane the variations are considerable, but as lamps are usually hung with the axis vertical and base upward, the illumination in the useful directions will not differ much from the illumination in the horizontal plane, and the illuminating power of an incandescent lamp is, therefore, nearly the same in all useful directions, and is practically that for which the lamp is marked. Figs. 1 and 2 show the distribution of light in the horizontal and vertical planes, respectively, by actual measurement, of an incandescent lamp marked 16 candle-power. It will be seen that in the horizontal plane the distribution is practically uniform, and that in the vertical plane the illumination falls only to 15 candles at 30° above and below the horizontal. It will be noted, also, that the illumination is greatest in the horizontal plane.

With arc lamps the case is entirely otherwise. While the distribution in the horizontal plane is uniform, its intensity is but a fraction of the maximum intensity of the lamp. This is shown in Fig. 3, which represents the distribution of the light in a vertical plane from an arc lamp consuming 10 amperes at 45 volts, a so-called 2000 candle-power lamp. The maximum illuminating power—1200 candles—occurs at 45° below the horizontal. From this it rapidly diminishes to 500 candles at 15°, and 300 candles at the horizontal.

A great deal has been said about the proper rating of arc lamps. The true rating will depend upon circumstances. In comparing two sources of light, considered as means of illumination, it is evident that we must compare the useful light of the one with the useful light of the other. If the total light emitted can be made useful in both cases, as is practically done in light-house illumination, the relation of the two sources is the ratio of their mean spherical candle-powers. If the light is wanted only in some one direction, then the relative value of the two sources is the ratio of their light-giving powers in that direction. If the object is street lighting,

and all parts of the street need the light equally, then the value of the source must be determined by its effect where the illumination is least. With this understanding, let us consider the relative values of arc and incandescent lamps in street lighting.

If arc lamps are placed at intervals of 500 feet, the illumination is least at a

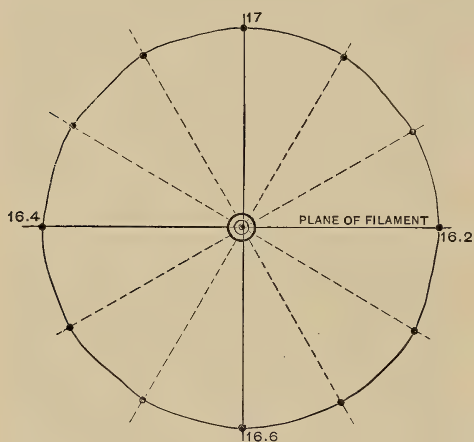


FIG. I.

point midway between them, and if the lamps are hung at an elevation of 25 feet above the street the direction of the light to that point is along the line marked $\frac{1}{10}$ in Fig. 3, where the intensity is 350 candles. The arc lamp used for this purpose is a 350-candle lamp. Its greater intensity in other directions is useless, since it serves only to illuminate more strongly points nearer the lamp. In fact, to obtain upon the street, at a distance of 25 feet from the vertical through the lamp, that is, on the line marked 45° in Fig. 3, the same illumination as is obtained at 250 feet, only a 7-candle lamp would be needed, and the intensity of the light from the arc lamp along that line is, therefore, 1193 candles more than necessary.

This arc lamp requires 450 watts. The same power at 3.5 watts per candle would supply eight 16-candle incandescent lamps. Substituting these for the arc lamps on the same street, the distance between them would be only 62.5 feet, and if suspended at a height of 20 feet, the most distant point from any lamp would be 37.5 feet, and at that distance the 16-candle lamp would give 1.6 times the illumination that the arc lamp gives at 250 feet. That is to say, if 16-candle incandescent lamps, consuming the same power, be substituted for the arc lamps along a street, the darkest place will be 1.6 times as light as the darkest place with the arc lamps.

These facts lead us to ask if there is no way to prevent the enormous waste of light due to the peculiar distribution from the arc lamp. The cause of the peculiar distribution is well understood. In the ordinary arc, requiring 45 volts and 10 amperes, about 38 volts are used to overcome the counter-electromotive force of the arc which has its seat at the small concave surface, known as the "crater," at the end of the positive carbon. About 380 watts are, therefore, expended upon this small area, raising the carbon to an extremely high temperature and converting it into vapor to supply the arc. The remainder of the energy is expended in the arc itself and the other resistances of the lamp. The heat of the crater extends to other portions of the positive carbon near the end, raising it to incandescence, and the heat of the arc also raises to incandescence a portion of the negative carbon.

FIG. 2.

These surfaces, at a comparatively feeble incandescence, supply all the light above, and most of that down to 30° below the horizontal plane. The intensely luminous crater, on account of its form, can emit light only over a zone included between about 30° and 55° below the horizontal. This distribution

varies somewhat with the character and size of the carbons employed, but it cannot be materially changed.

For interior illumination the lower carbon is sometimes made the positive carbon, thus throwing the zone of intense light into the upper hemisphere, where it falls upon a white ceiling or other suitable surface, which then becomes the source of light. An arrangement furnished by the Siemens & Halske Company, illustrated in section in Fig. 4, permits of the use of the upper carbon as the positive, and secures the same result. A ring, G H, of triangular section, receives all the intense rays and deflects them upward, causing them to strike the white surface, A, B, E, F, which then sends them downward in various directions, illuminating quite uniformly the space below. These methods serve a good purpose for interior illumination, but for street lighting, where arc lamps must of necessity be placed at considerable distances, quite other methods must be employed.

Recognizing the fact that the most intense light is emitted in a direction obliquely downward, the attempt was at one time made to utilize more fully the rays of high intensity by placing the lamps on towers from 100 to 150 feet high. But to save the expense of so many towers the great mistake was made of grouping several lamps on one tower, and placing the towers at long distances apart, thus losing all the advantage of the great elevation of the lamps. Even if the lamps, however, had been suspended singly and distributed at the great elevation evenly over the space to be illuminated, the full benefit of the light would not have been obtained, since the most intense rays would illuminate a circumference whose radius was the height of the lamp, leaving the more distant points to be illuminated by the more feeble rays. The reverse of this is what is wanted. The most intense rays should illuminate the most distant, and the more feeble rays the nearer points. This would be pretty fairly accomplished if the order of the rays from the horizontal to about 50° below could be reversed.

In Fig. 5 I have indicated a method by which this may be done. Suppose two rings of glass, of which A, B, C, D and F, B, C, E are cross sections by a plane passing through their common axis, to be placed as shown in the figure. The 1200 candle-power ray, falling upon the lower ring near A, is refracted along the dotted line, and, striking the surface, A D, at an angle so great that it cannot emerge, is totally reflected toward C, and emerges from the surface, C D, in a direction nearly

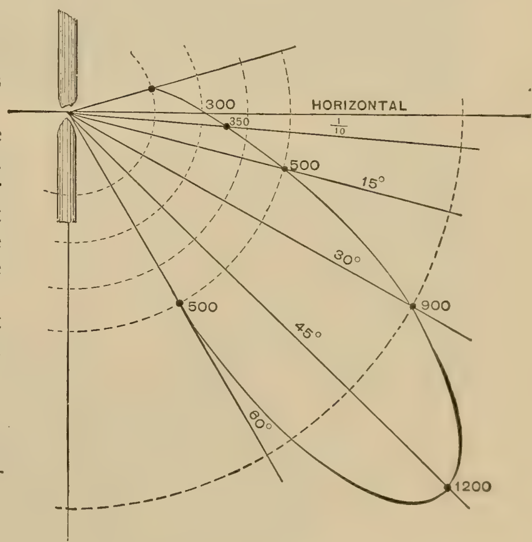


FIG. 3.

horizontal, or in such a direction as to reach the farthest point which that lamp is intended to illuminate. Following the course of the other rays, it will be seen that the rays of less and less intensity are, after emerging from the rings, directed more and more downward, so as to illuminate points nearer and nearer the lamp. Finally, the still more feeble rays, from the horizontal upward, fall upon a conical reflecting surface, G H, which may form part of a hood covering the lamp, and are reflected downward, so as to illuminate the space directly below. To avoid loss of light it would be necessary that all the surfaces of the glass rings

should be ground and polished. With such rings the loss would be no greater than would occur when the light passes through polished plate-glass.

Even with this arrangement, by which the most intense rays are sent to the most distant points, those points are not as well illuminated as the nearer ones, because the intense rays are not intense enough to compensate for the greater distance. This may be remedied by giving to the surfaces, A B, F B, a suitable curvature, concentrating the rays somewhat toward the distant points at the expense of the points nearer by. Such an arrangement as this would be somewhat expensive, and would necessitate the use of a focussing lamp, but it would render the arc lamp at least four times as efficient for street and other out-door lighting.

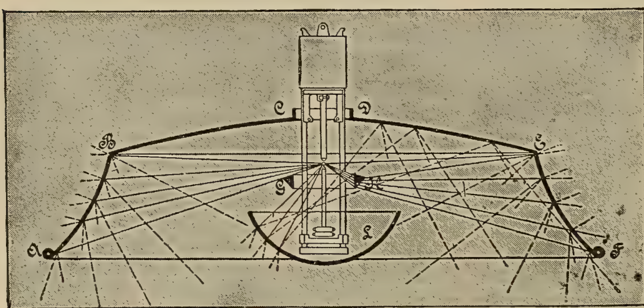


FIG. 4.

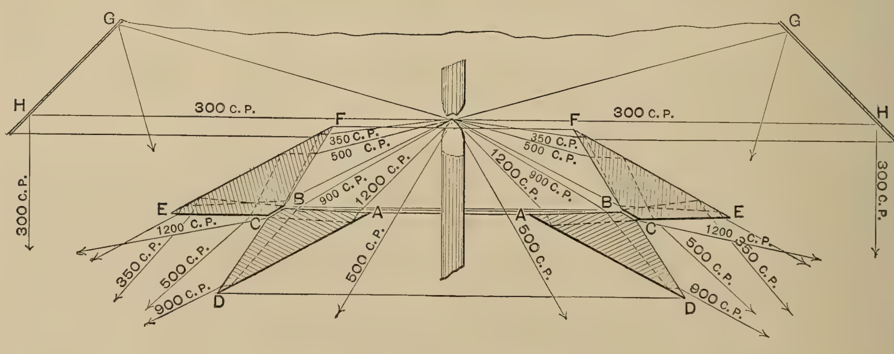


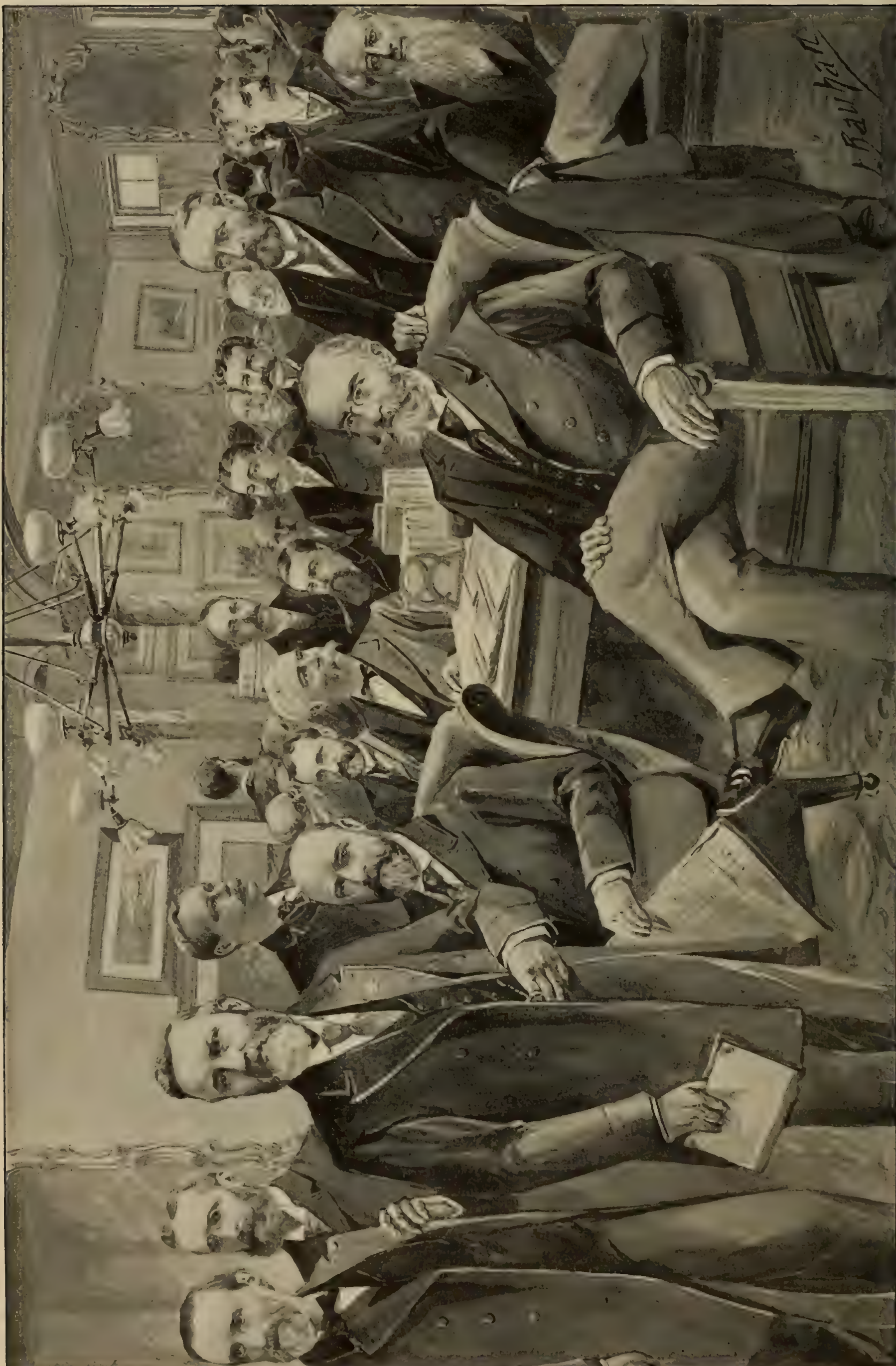
FIG. 5.

When we consider in-door lighting of workshops, salesrooms and other rooms where work is carried on, the circumstances of each particular case will usually determine what is the best mode of lighting. It may be laid down as a general principle that the nearer we can approach to diffused daylight, the better will the illumination serve its purpose. The source itself of the light, whether incandescent or arc, should, if possible, be invisible. The light should fall upon the work, not in the workman's eyes. The light should, moreover, come from many points or from a large illuminated surface. Whatever the lamps used, they should be distributed as uniformly as possible over the space to be lighted. Placing lamps, either arc or incandescent, in groups or clusters, is never to be recommended, unless, for some reason, one part of a space needs the light more than another. Where uniform illumination is desired there is no excuse for grouping lamps, except convenience in installing, and any such grouping is at the expense of uniformity of illumination.

When a space is to be illuminated by general diffused light, apparatus can be arranged to utilize to advantage all the light of the source. Under such conditions the arc has the advantage of the incandescent lamp in point of effi-

ciency, since it gives from 300 to 500 mean spherical candle-power for 450 watts, or one candle for from 1.5 to 0.9 watts, while incandescent lamps will not do much better than one candle for 3 watts. The method employed is to throw the light of the lamp upon a large white surface, which then becomes the luminous source, as has been so well described by Mr. Dobson in the March number of this magazine, where the ceiling and walls of the room receive and then emit the light. The use of a specially prepared surface for this purpose, forming a part of the lamp outfit, has already been referred to in this article and illustrated in Fig. 4.

In conclusion it may be said that an arc lamp must be rated according to the manner in which it is used. If the rays near the horizontal are most important, then the so-called 2000-candle lamp is about of 300 candle-power. Instead of giving, for the same energy expended, ten times as much light as the incandescent lamp, it gives only two or three times as much. There are many cases where, in consequence of the subdivision and more uniform distribution of the light, incandescent lamps give a better illumination than arc lamps consuming the same energy. This is especially true in street lighting, where the distribution is a linear one.



A PART OF "OUR CLUB."

OUR CLUB.

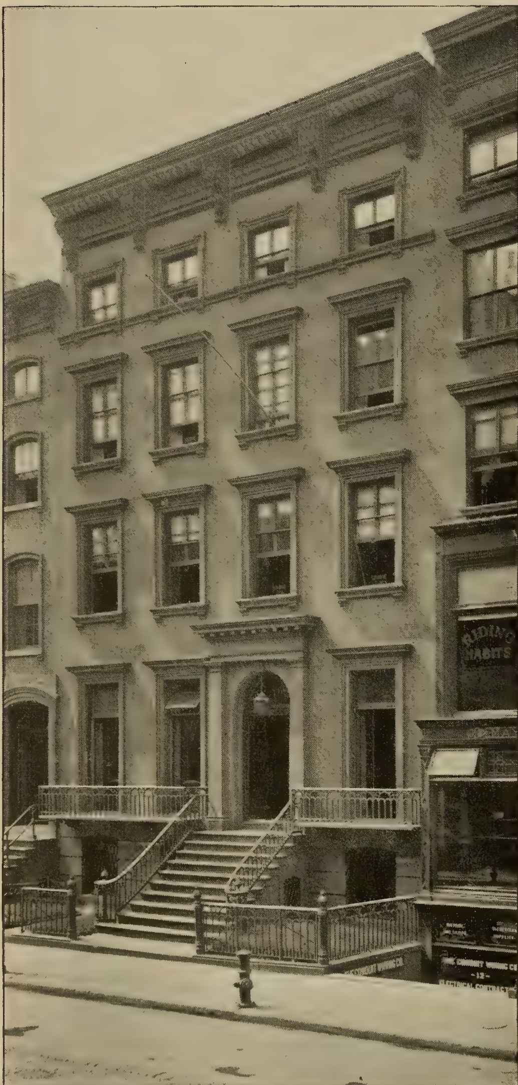
By J. F. Holloway, Past Pres. Engineers' Club.

THERE are clubs and clubs, and no doubt the city of Gotham contains within its borders quite as large a number of them as does any city in the world. If the definition of Dr. Johnson was a correct one when he said that a club was "an assembly of good fellows, meeting under certain conditions," it is quite impossible for us to imagine a time when clubs did not exist, for there must have been "good fellows" in all ages of the world, and they must have at times met, though certainly not always under like conditions.

Imagination, which disregards time and place as readily as it does truth, might easily paint for us a picture of an old-time club wherein Patriarchs, feeding their flocks on Chaldean plains, but recently enriched by the receding waters of the flood, might be seen leading them beside rivers whose waters, as yet unpolluted by protoplasm or bacteria, rippled and sparkled as they flowed onward beneath the brightness of an as yet unspotted sun, and who, finding, as the eventide approached, other "good fellows" under the shelter of tree or tent, formed, then and there, a club; certainly not a club housed in palaces of architectural splendor, and filled with the refinements of such a luxurious age as is this, including the inevitable "check pad," which no ingenuity can well dodge, but why not a club of "good fellows" whose duties and avocations would permit of such gatherings, where, as the shadows faded out and the stars shone forth, they could fill the hours with talk of seed time and harvest, of increasing herds and flocks and possibly of tariffs on wool. While we are at times prone to claim that "engineers' clubs" are the result and evidence of high and recent civilization, what was there to prevent their existence in the palmy days of that oldest nation of the world, who at the Centennial came to greet the youngest? Is it hard to imagine that the youth, who, lifted from out a pit (which might seem to indicate that he was even at that time a mining engineer) and sold into a foreign land, where, by his engineering ability, he earned a title higher even than that of prime minister to Pharoah, might also have been the president of an "engineers' club" on the banks of the Nile?

While it is scarcely permissible in clubs of this kind to introduce shop talk, was there not in the achievements of our brethren in those far-off days much that they might have talked about with interest and profit? Did not the contrivances with which the work of building, from the plains upward, the great pyramids, furnish themes for argument and discussion, and when the topmost stone crowned the summit of Geza, and when, resting on its base, Cleopatra's needle first loomed up in the Egyptian sky, were there no hand-shakings, no engineers' banquets and speeches? All remember the pomp and ceremonius splendor with which the opening of the Suez Canal was celebrated. Christian and barbarian kings united to honor the engineer and the event; the reigning

empress of one of the foremost nations of the world graced it with her presence and her beauty ; a great master of melody, whose music had charmed a past generation, bent himself anew to the task to give in triumphal marches and in the stirring strains of trumpets and horns, tinkling cymbals and beating drums, as well as in the restful cadence of sweet melodies, all set amid the splendid groupings of Oriental scenery and costumes, an opera which, performed beneath an Egyptian sky, glorified and embalmed the event in the memory of all who heard and saw it. And yet, after all, the event celebrated was, for the most part, but the rescuing from the encroaching sands of the desert the canal of Joseph—a canal that certainly must have been talked over and discussed in some then existing "engineers' club."



THE OUTSIDE.

Clubs of later ages are known to us more or less, but who is there who would not gladly know more about them ? What a treat it must have been to have listened to the words of Shakespeare, Addison, Fletcher, Sir Walter Raleigh and others who, beneath the roof of the "Mermaid," were wont to try their lances in contests of wit and humor, and where, as Beaumont says, men heard "words that have been so nimble and so full of subtle flame, as if every one from whom they came had meant to put his whole wit in a jest."

As the illustrations that grace these pages are of "The Engineers' Club of New York," it will be proper here to say something of its conception, its aims and success. When on the evening of February 3, 1888, a few gentlemen met together in a private parlor of the Victoria Hotel to consider the advisability of forming a social club, where engineers, engaged in various branches of the profession, could meet each other to renew acquaintances, in many instances well-nigh forgotten, and to form new ones ; to found a common centre about which resident and non-resident members might meet amid associations and conditions certain to engender a home-like feeling not otherwise attainable in so cosmopolitan a city as is New York, it is fair to assume that among the most sanguine advocates for the formation of the Engineers'

IN THE OFFICE.

Club, there were none who dreamed of the great success which it has, in so few years, attained. Organized with a charter membership of fourteen, it has now attained a membership of nearly 700, and this during years of depression in business that has made serious inroads in many old and well-established clubs. While the home of the club comes far short of the grandeur that pertains to many of the older clubs of New York city, it has in and about it what the artist is wont to describe as "an atmosphere"—a something which, in its indescribable influence, seems to, as Shakespeare says, "make all akin." The artist with a license and a liberty always claimed, and always conceded to his profession, has at his sweet will grouped in the various rooms of the house members who were more or less closely identified with the early history of the club. Whether the classfications and surroundings are in every instance just what they should be, is a question he must answer, but that each and every one whom he has delineated are of the class of persons described by Dr. Johnson as necessary to make a club, none who know them will for a moment doubt.

It would seem, judging from the composition and arrangement of the different groups, that the artist was unaware of the existence in the club of an unwritten law which taboos "shop talk"—not that "shop talk" is actually going on in the pictures, but they do suggest its possibility. Disregarding the largest group shown, where, without doubt, the conversation indulged in is by no means on subjects strictly technical and professional, the picture on this page would indicate that if a dissertation on combustion was not being given, at least an illustration was about to be shown.

To those who imagine that they

A CORNER IN THE DINING ROOM.

recognize in the picture above friends and acquaintances, there will come a suspicion that the value of the heat units contained in various substances is being discussed, and that the merits of "buckwheat" and "pea" have there an earnest and able advocate. Further on comes a scene that seemingly would indicate that the subject of clothing was being warmly discussed, at least by one of the parties, and that jackets of the best style, and filled with steam, were being earnestly recommended.

The library scene is properly a quiet one, wherein no special discussions disturb the equanimity of the gentlemen present, and if a vote were to be taken, the result undoubtedly would be unanimous. In an adjoining room is a quite different scene, one person having the floor while his associates are prepared to take notes. Whether the debate is in regard to ballistic tests, and whether the shots fired by the speaker, and evidently aimed at the vacant chair, had anything to do with driving its occupant out, will be known only when the notes are published.

In the department devoted to hydraulics, it is still more difficult to divine just what matter is being thus gravely considered; possibly it refers to the danger of using water to which a suspicion of bacteria attaches. An objection might readily be made to the scene that follows, as being far too professional and technical for such a place. The table, evidently a drawing one, is, without doubt, used to illustrate the value of different angles in producing certain desired results, and also to show how carefully constructed curves, when properly used, contribute greatly to the general result as tabulated on the blackboard. Just what problem is, at the time, being worked

out can only be ascertained from the head master, who, it seems, is temporarily absent. The quiet repose suggested by the closing illustration seems appropriate to a degree, and it will no doubt be gladly welcomed by all who shall have endured to the end.

It has been stated that the purpose which they belong. While many engineers have attained position and influence in the various engineering societies of which they are members, and while their researches and investigations as revealed in the published transactions of such societies, together with the fame of their accomplished works,

ONE OF THE PARLORS.

of the Engineers' Club is to promote a better and wider acquaintance among engineers. There was in the minds ot its originators a still broader purpose, and that was, to promote among the general public a better knowledge ot engineers, and ot the profession to have been spread abroad, and perchance, as is often the case, have there earned for them recognition not accorded them at home, as individuals simply, they exert but slight influence either in society or public affairs. But when in a club or in similar associations such

A GLIMPSE OF THE LIBRARY.

men are grouped together, men who, as leaders, have moved forward in the vanguard of progress and civilization, whose skill and ingenuity have covered the seas with swift moving ships, bridged mighty rivers, and over sterile planes, up the ascending foot hills and over and beyond the mountain crests have leveled a highway which, ribbed with steel, bears to and fro the traffic of continents with celerity and ease, and as well men who, delving fathoms deep into the storehouse of Nature, have brought into the sunlight her gems, her ores and metals, which, in the alchemy of forge and furnace they have fashioned into forms of usefulness and beauty—who will not concede to such men, place and position, in affairs where culture and intelligence form a necessary adjunct.

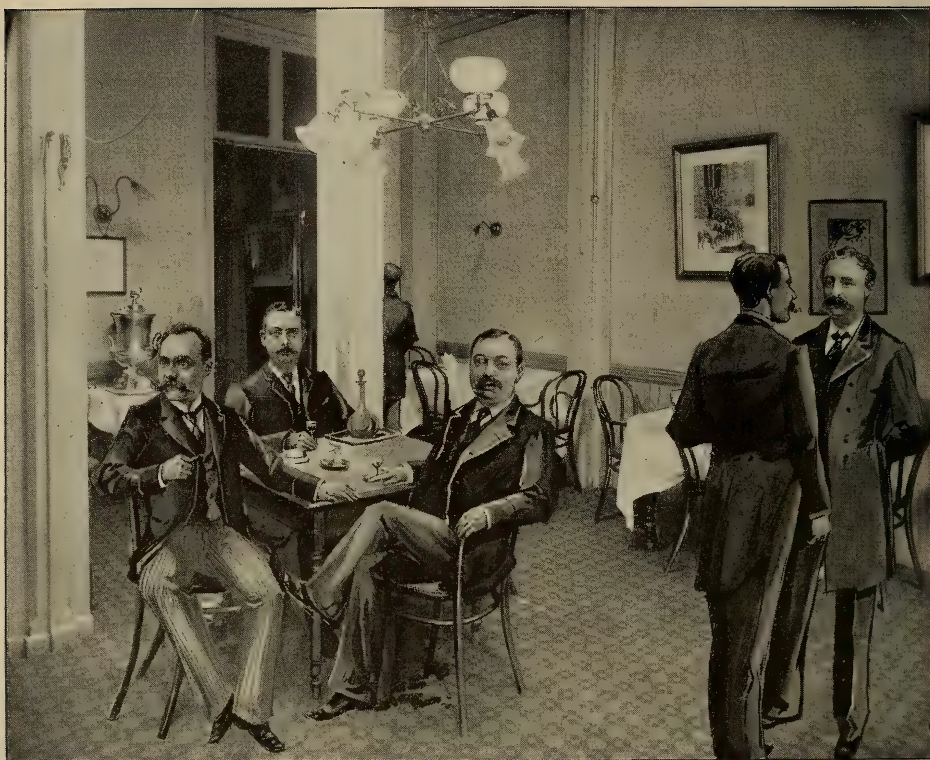
The house of the club is a convenient place in which to discuss or consider questions relating to social matters, and, as well, to plan and perfect arrangements for the entertainment of engineers and engineering societies of other lands. It was here that was planned the programme of one of the largest and most extended excursions of the kind ever had, where members of the Iron and Steel Institute of Great Britain, and, as well, eminent engineers from the European Continent were taken in two enormous trains of Pullman cars over a territory reaching from Lake Superior to the Gulf of Mexico, and that, too, with a degree of celerity, ease and comfort that was a marvel to guests and a great credit to the members of the Engineers' Club, who controlled and managed it.

One of the successful methods early adopted by the club, by which to bring about that feeling of goodfellowship for which it is noted, is the custom of having, during the winter, informal dinners. It is on such occasions that the busy resident member finds opportunity in which to meet his acquaintances and

neighbors ; it is here that the non-resident member, whose visits are less frequent than he could wish, is certain to find, if not old acquaintances, those who, as new ones, will strive to make the absence of the others less regretful. Grouped under the mellowed light of the shaded lamps, the after-dinner members devote themselves to the discussion of current affairs and to reminiscences, as each, in his own way, smokes his favorite cigar and toys with its ashes. Sometimes the artist engineer, who paints a picture, builds a bridge or writes a book with equal ease and credit, is deftly and unconsciously led to recount the story of some trip along the Mediterranean, where, half idling, half painting, he floated along the canals of Venice and under its bridges ; and, as he describes how the sinking sun for a moment brings out the old-time splendor of palace walls and towering campaniles ere it disappears, you almost fancy that you look upon the scene ; and, later on, as the twinkling lights of the moving gondolas come over the waters, your ears seem to catch the gentle ripple of the waves under their bow.

Then, again, some famed naval engineer would recount tales of the sea, mayhap it be of storm or shipwreck ; or, perchance, some spoken word will bring back to him the memory of gone-bye battles, had in Hampton Roads, or off the coast near Beaufort, or Charlestown, where, in the stifling heat of the between-decks of some famous monitor, he handled the engines as they swung the hull into the line of battle, or slowly revolved the massive turrets, on whose battered plates the hail, from guns ashore, left enduring evidence of power and accuracy of aim. Intermingled were tales of adventure in

A PRIVATE DINING ROOM.

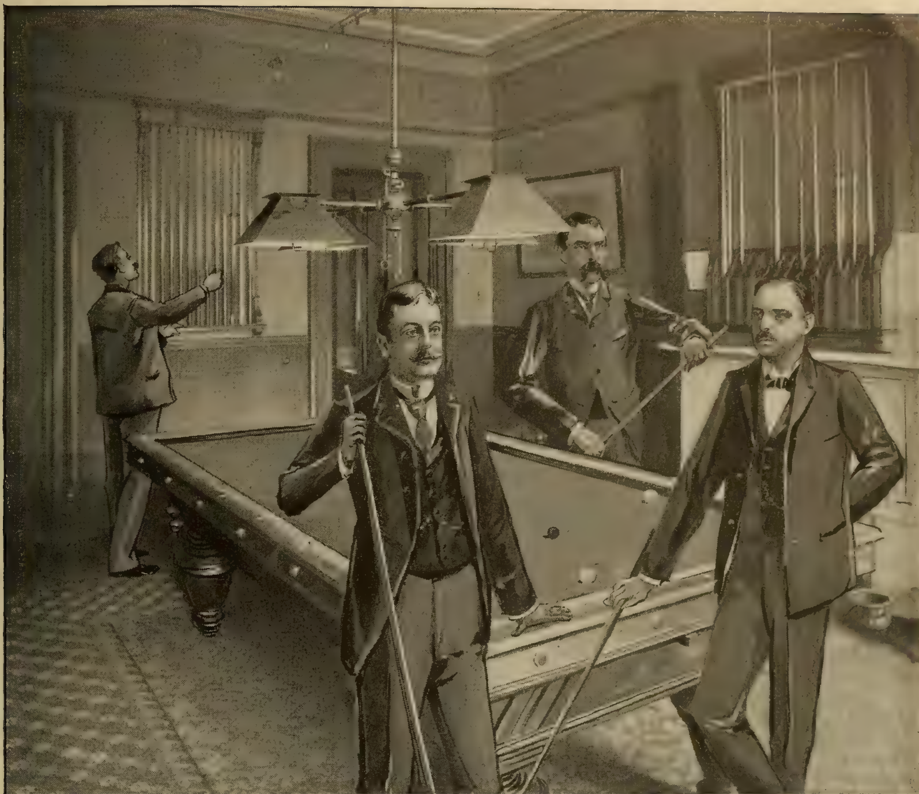


THE CAFÉ.

native and foreign lands, on mountain heights or in valleys deep, through the rank jungle of the tropics, or amid the everlasting fields of snow and ice, which, in their solemn silence and grandeur, hedge in from the zeal of the most enthusiastic scientist, and the footsteps of the most daring traveler, those weird mysteries which cling about the magnetic pole, ever inviting and luring them on, but which are never to be revealed to mortal eyes.

'Twas such a tale, was told one winter's night by a famous engineer who, himself, was one of the very few survivors of an ill-fated Arctic expedition. To those who listened to the story, no description is necessary ; to all others, no words other than those coming from the lips of one who, even after the lapse of years, recalled with ease the horrors of the situation, could do it justice.

Often an interested group would listen with interest to the story of some mining engineer, it may be, but just returned from a trip to South America, or from some far-off island in the Indian ocean where he had searched for special ores or metal. Sometimes it is one fresh from Africa's sunny land, who talks of Zulu and Mashonaland as if they were but outlying districts, and of their dusky kings and potentates with the familiarity of a ward politican. Urged on, he tells of long journeys inland where, at last, the bone-breaking ox-cart brings one to rocky ledges, glistening with precious metals, or to diamond mines, rich beyond the wildest tales of Aladdin, in the strong room of which he was shown spacious drawers wherein there lay in startling abundance the pebbles that later on will be transformed into the brilliants that are to sparkle in the coronet of a duchess,



ONE OF THE BILLIARD ROOMS.

or in the necklace of a successful speculator's wife. And as the relator tells his listeners that these uncut jems are moved to and fro with scoop shovels of medium size they realize something of the output of the famous diamond mines of South Africa.

Other groups listen to tales of lighter vein, it may be of hunting, or perchance, it is a city official who talks of a vacation but just over, and of streams wherein he idly cast his line and, finding the finny tribe grouped in distinct layers or strata, he was enabled to bring up any desired kind of fish by simply sinking his baited hook to the proper level. Possibly some listeners might have been disposed to question this, to them new, discovery in natural history, had it not been that the relator was a prominent representative of a department of the city government whose province it is to furnish to the public facts and statistics of unquestioned accuracy.

There are among the members of the Engineers' club many gentlemen to whom the gift of clothing their ideas with the imagery of appropriate words has been denied. They are literally men of deeds, not words, and their deeds are to be observed by all men. They are to be seen in far-reaching railway lines; in spacious bridges, whose foundations are laid deep and strong; in splendidly equipped iron and steel plants; in magnificent steamers, and in a thousand ways which benefit and add to the comfort of their fellow-men.

It is, however, the good fortune of the club to have members who, in addition to other accomplishments, have the rare ability to be able to give utterance

in prose or verse to what others feel, but cannot fitly express.

Who, that was privileged to listen to our versatile member and mining engineer, can ever forget the splendidly painted word picture he gave us in an after-dinner talk, and which might well have been called "The Vision of the Canyon of the Colorado?" From start to finish it was a moving panorama, in which nothing unimportant was included, nothing necessary to its completeness omitted. With him we traveled by day and camped by night until, moving onward and upward, he suddenly halted us on the brink of the most wonderful sight of that land of wondrous sights—the "Canyon of the Colorado," where a vision was spread before us, such as rarely comes to mortal eyes. Below, hundreds of fathoms, a brook-like looking river dashed and foamed over its rocky bed, and as seemingly we clung to rocks and trees as we hung over the brink, gazing into that awful chasm, we knew not which outdid the other in sublimity and grandeur, the glowering darkness of the pit below, or the glowing splendor of the azure blue above and around us, which, in the ecstasy of its buoyant air, tempted us to follow the flight of imagination of the gifted speaker, as he almost lifted our feet from off the mountain's crest, and later in the evening, as we went out into the night, we felt as if we had unwillingly been brought back to earth again.

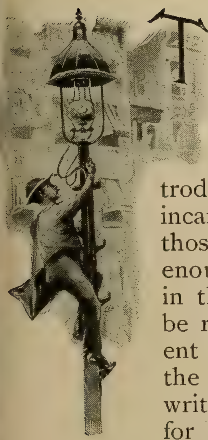
Club life, like the home life, has its sorrows as well as its joys. The sad days are those when, bordered in black, there appears on its bulletin board the announcement of the death of a member and friend. His taking off may have been in some distant land, where, in the pursuit of his profession, he became the victim of diseases incident to his surroundings, or it may have come

A COZY BED ROOM.

to him at home and among friends, and after a long and brave struggle, in which indominatable will had well nigh won in the "battle of life;" but come when and where it may, its announcement is sure to bring sadness to those who read it, and as they look upon it, the memory of their friend comes back, his faults forgotten, his virtues cherished, and as they turn away their silent comment in "Our Club" is, "he was a good fellow."

REMINISCENCES OF BY-GONE ELECTRICAL DAYS.

By Fred A. Scheffler.



THERE are, without doubt, many persons among the electrical fraternity who can recall various peculiar circumstances and results attending the sale or introduction of the electric light, incandescent or arc, particularly those who were fortunate (?) enough to have been in the field in the early days. It may not be remiss to record at the present time some recollections of the method adopted by the writer and others known to him for effecting sales or introducing the electrical apparatus to certain unbelievers in such cases where the usual truthful stories would not be believed, especially where the use of the arc lamp was compared with that of the incandescent, and the latter with the cost of gas.

I have no doubt that were the experiences of many of the representatives of the electrical companies placed on record, dating from 1881 to the present time, there would be many volumes of excellent and amusing reading matter; but this particular paper relates simply to the days of 1881 to 1884, and covers, of course, only a few such actual facts as befell the writer.

There is no question but that in the infancy of the sub-divided or incandescent electric light the first cost was more of a luxury than otherwise. While the operation of the plant (I refer more particularly now to "isolated plants") could easily be shown, by simple arithmetic, to cost materially less, including even the interest on the investment, when compared with the cost of gas, at the prices the latter commodity was selling for twelve years ago, at the same time a sale of goods required much persuasion and many visits to the customer. If it is borne in mind that a sixty-light incandescent dynamo at that time was as expensive as a 300-light one is to-day, one can readily appreciate the statement made above, and also obtain an idea of the remarkable results brought about by competition and time. Not only were dynamos expensive, but the lamps and sockets also were scheduled at five times the present prices. Sixteen candle-power lamps cost one dollar and a quarter each, and the guaranteed life was no greater than it is to-day at thirty cents. Key sockets were a dollar each, and were not so well made either as the socket selling to-day at twenty cents.

To tell the truth, these prices did not stand for many years; furthermore, the business transacted was exceedingly small for the first two years, considering the capital invested and the vast expense always accompanying the introduction on a broad scale of any new but practical invention.

Thirteen years ago one of the first private houses wired for electric light (Edison system) was that of Wm. H. Vanderbilt, at New York. As the house was of ample proportions, and the owner had no particular reason for "reducing

expenses,'' the number of lights of sixteen candle-power each for which the building was wired was in the neighborhood of *nineteen hundred.* Imagine a bunch of number ten wires (each about an eighth of an inch in diameter) as large as three inches in diameter leading from the house to the street for the ''mains,'' and you may conceive something of the enormous amount of current at one hundred and ten volts which it was anticipated would be required when the entire house was illuminated. If I remember the figures correctly, there were five *tons* of copper wire utilized in the wiring of this residence. The mains were prepared for connecting to the street and from thence to the generating station, when the latter was erected, which was not until several years had elapsed. For immediate use it was arranged that a small isolated plant should be placed in the basement, and immediately under the covered passage connecting this residence with that of Mr. Twombly's.

The plant was so small that not more than 120 lamps out of the entire 1900 could be utilized, and it consisted of a locomotive boiler, designed by the writer, and built by the Baldwin Locomotive Works, and a pair of Armington & Sims engines connected by belting to a counter shaft, which, in turn, was belted to two Z dynamos, each of sixty lights capacity.

On a certain evening the Vanderbilt family came to the house, when everything was in readiness, to witness the illumination of the halls and various rooms. This arrangement called for several of the representatives of the Edison company to be ''on deck'' to see that the exhibition became a success in all respects, as the criticism of such a family meant, if favorable, much business for the electric company, and if unfavorable, exactly the reverse, but in a far greater degree. One of the earliest ''kobolds'' which ever came to my notice made its appearance on that evening. On the second floor, fronting Fifth avenue, there was a large room handsomely decorated with ''cloth of gold.'' This material covered the walls in a manner similar to that of wall paper. On the sides of the room there were several combination gas and electric brackets. The ceiling contained quite a number of single electric pendants distributed around the four sides. The combination fixtures also were wired for lighting the gas by electricity. For some unknown reason this room had not been previously tested by the current from the dynamos, and the accident which occurred was all the more surprising to those who were present. There must have been a ''short circuit'' from one of the brackets to the wall plate which came in contact with the fine threads of gold which were woven in the cloth covering the walls and ceiling. One of the pendants above was similarly short circuited. When the switch was closed a streak of electricity shot from the brackets in a zig zag fashion to the ceiling, and as long as the switch remained closed the current would take new paths among the metal threads, leaving behind it a disfigured wall. From a scientific standpoint the effect was most brilliant and vivid. The scene only lacked the thunder furnished by the ''property man'' to make one think of the stormy night which Rip Van Winkle had to face when he was driven away from his home. From the bracket to the floor the covering on the wall was parted in a perfectly straight line, and the edges were as clean and smooth as though they had been cut with a knife specially sharpened for the purpose. Of course this room was kept locked after the above performance, and the family did not see it illuminated. It cost the Edison Company a ''pretty penny'' to make the necessary repairs, although there was considerable doubt about their being the only ones who were responsible for the bad work ; directly, however, there could be no question about the accident resulting from the Edison current.

Unfortunately, Mrs. Vanderbilt had no particular fancy for residing immediately in the vicinity of a steam engine and a boiler carrying 120 lbs. steam pressure, not taking into consideration

the "hum" of the machinery, which was indispensable, and that evening's exhibition concluded the farce of the Edison-Vanderbilt combination with the ordering out of the entire plant.

The continuation of the outfit would only have resulted in its being used as a plaything, for 120 lamps would scarcely illuminate the ball room or art gallery.

It was quite customary for the Edison Company to keep its "eagle eye" on all new buildings under course of construction, and among those which were fairly well along in 1883 was the "Eden Musée," at New York, containing the well known wax-works collections. Just what it was intended to be used for was scarcely understood by the majority of persons who watched its progress, but it shortly became known to the Edison Company that the owners contemplated lighting it with many thousand gas jets. Here was a golden opportunity for the Edison Company to sell these people some money, for could it not be mathematically demonstrated that by using the electric light the cost of same would be far below that of gas for the same candle-power-hours? After interviewing the foreigner in charge of the work on behalf of the Eden Musée Company. who could scarcely speak English, it was discovered that he had an abhorrence for "ze electric light," and pronounced himself as being unfavorably inclined to consider the matter in any manner whatsoever. This was very good for the first lesson, but we were not to be downed so easily. The next interview with this party elicited the information that he had tried this method of illuminating in a house abroad, and it was so defective that nearly all the wax works were spoiled—the light was so ghostly. After many protestations by the writer to the effect that he surely was mistaken, and that *our* electric light was altogether different from the kind the gentlemen referred to, I was most emphatically informed that he knew an electric light when he saw it, and that there was only one kind. After much discussion, in which you will see that my French failed me entirely in endeavoring to make myself understood, the inquiry was launched at my head as to the cost of *one light* to be placed outside for an advertisement.

To think that the result of all my endeavors with this party with a view of educating him to appreciate and understand the incandescent lamp should only prove that he had but one idea of an electric lamp, and that was the kind "out in ze square," as he described it—an arc lamp! While there was no love about my discussion with him, there certainly was much *labor lost.* I afterwards found that this French gentleman was not the manager after all. The latter party arrived in New York a short time after the above discussion occurred, and to him I repeated the story of what we desired to do and why. I found Count Sartere, the manager, a very amiable person, and had no difficulty in demonstrating to his entire satisfaction that the Eden Musée would be a failure without the Edison light. If the Chamber of Horrors was to be illuminated by gas jets it would certainly become so foul a place that the name would not be a misnomer.

The success, from an illuminating standpoint, of this resort has been superior to any other similar institution hitherto constructed by the Eden Musée Company.

A good story is told of the competition between the representative of the Brush Electric Company, Major ——, on behalf of the arc light, and the Edison Company's excellent advocate, Mr. B., for the lighting of a certain factory not far from New York City. These gentlemen called on the same day to present their respective claims to the owner, who was a German, as to why the "other fellow's" system would not be suitable for the purpose. Of course the Major argued that his arc light was very much cheaper to operate, and the purchaser would obtain thousands of candle-power in excess of the incandescent lamps and for less money expended in the first cost. Naturally Mr. B. contended that the owner

could not use the arc lamp, because it "flicked" so badly that the employees would be seriously hampered in their work, which required the very best of illumination, and the Edison system could be so utilized that each employee could have a lamp immediately under his or her own control, and as for operating expenses, "it was far cheaper and safer than gas."

"Vell," said our German friend, "dat's pooty good, too; you shust draw me up dose babers and I giv you der order in der morgen."

Joyfully our friend Mr. B. wended his way towards the finest hotel which the town was guilty of supporting, stopping in the telegraph office on his way to announce the glad tidings to the home office, and advising them that the particulars would be sent later. Little did he imagine that the particulars which were to be given later would be carried in person, and be of a very different nature from that implied in the message. Mr. B., after having handsomely taken care of the inner man, lighted one of the good cigars which he was always well supplied with and proceeded to draw up the formal proposition, specification and contract. How contented he was, laughing at times as he thought of how well the Major had been tricked out of that plant—and anyone who could thus "do him up" must be a particularly competent party, for the Major was no fool. To say that Mr. B. slept well that night would not be doing him justice.

And what of the Major? Did he take the first train home that evening vowing vengeance on B's head? Not he. After darkness made its appearance, if I may be pardoned such an expression, he sought the German gentleman and invited him out to investigate certain facts pertaining to the arc lamp as it appeared on the street corner. The result of this investigation may possibly be told to better advantage by relating the experience of Mr. B. on the following morning. That gentleman was up betimes, bright and early, prepared with all the necessary documents and forthwith hied himself to the office of our German friend, as per special appointment. The office boy presented Mr. B's card to the proprietor, who sent word out that he would see him in a short time. After waiting much longer than the "short time" our incandescent contractor concluded that he had been forgotten, and said to the boy, "tell Mr. B. that I had an appointment with him for 8:30 this morning and it's an hour after that time now. I would like to get through with my business and go back to New York."

The boy disappeared, and in a few minutes who should walk out of the office but the Major. In meeting Mr. B. both gentlemen were particularly affable toward each other. One because he had a signed contract in his pocket, the other because he doubted not the promise of the purchaser who had invited him the previous evening to call in the morning and he would "giv him der order."

The proprietor greeted Mr. B. in a somewhat sheepish manner, and the following conversation ensued:

Mr. B.—"Agreeable to the appointment made last evening I have called this morning, and here are the papers covering my proposition. Will you please look them over?"

Mr. Proprietor—"I vas very sorry aber I cannot do any pisness mit you."

Mr. B.—"What do you mean, sir? You promised me the order this morning, and I have already telegraphed it to the works in order to hasten the delivery as much as possible. Do you mean to break your word?"

Mr. Proprietor—"Vell, I did exshpect to geep mine word mit you, but shoost after you left me last eavning de oder fellow he kom und showed me dot you toll me a pack of lies aboud dot big lamp. He say his lamp no flicker for my pisness."

Mr. B.—"Mr. Proprietor, you have been duped and have also played me false. You saw the lamp in the street flickering and that's just what you will get in your mill. Do you mean to tell me that the Major guaranteed his lamp would not flicker?"

"Ya, und I toll you how id vas. Der Major und me took a valk last night after you lef me und we shtopped by der lamp on der shtreet corner. Der Major said it vas all nonsense dot you said aboud dot lamp flicker and dot der engineer he make em flick for pisness like advertising. Peoples going by would nothing notice when dot lamp geeps quviet, and when dey see him flicker dey look up und see der name Brush on der lamp. Und the Major proved dis too by tooking oudt his vatch und say 'now he flicker efry vier seconds—there, see him flicker—in vier seconds he flicker again if dot engineer is doing his dooty,' und he did flicker. Aber I doant want any flicking lamps so der Major say he make der engineer geep em quviet and die brice is scheaper as yours so I giv der Major der order."

Wearily, but not crestfallen, our friend Mr. B. wended his way back to New York, and since this experience he has no doubt come to the conclusion that "one is never so sure until he is for certain."

As he is still selling electrical goods, and excellent ones too (the kind which elevate), there is no question but that he has lived to have his revenge by making good use of his early experiences and practicing occasionally upon his competitors.

One of the best known men in the electrical field told me recently of the manner in which he evaded a very serious question, put to him in the infancy of his electrical experience, and when he did not know an armature from a boot-jack. The competition this time was between the Brush arc dynamo and a Thomson-Houston. The representative of the former had advised the purchaser that the Brush machine had separate bobbins wound on the armature in such a manner that any one could be repaired in a very short time by simply rewinding that particular bobbin without interfering with the others, whereas the Thomson-Houston armature was so complicated that if any wires should become defective which were several "layers" down, the whole exterior would necessarily have to be removed. When my friend who represented the Thomson-Houston Company was asked to explain this apparent defect in the construction of their armature he was non-plussed for a reply, as he had never seen both armatures together and at that time did not know anything about the construction anyway, in fact was a greenhorn as far as detail was concerned. After hesitating a few minutes he replied (I wonder what particular god he worships?) that an explanation was very easy. The Brush dynamo was expected to and actually did burn out very frequently, hence provision for taking care of such an abominable occurrence, while the Thomson-Houston never burned out, in fact owing to the design that was impossible and therefore the company had no need to arrange to take care of rewinding. For this brilliant piece of truth (?) the Thomson-Houston party received the order for the plant.

To say in general that members of the electrical fraternity still have to resort to very peculiar methods at times in order to secure business, and that merit is not always the basis on which contracts are secured, probably expresses the feelings of many persons in that line of business; but thanks to the now general and frequent electrical "squibs" which appear in the best class of newspapers, and the many notes pertaining to the same subject which are printed in the magazines, the general public is not so apt to be "taken in" as was undoubtedly the fact in the early days of the electrical business.

SPECULATIONS ON CYLINDER CONDENSATION.

By John T. Hawkins.

THERE has been a vast amount of more or less exhaustive experiment during the comparatively recent development of the multi-cylinder steam engine, as well as a voluminous literature, looking to a satisfactory and definite knowledge of the exact behavior of steam within the cylinder during a revolution of the crank, and the procurement of means for the prevention of the losses occurring during such revolution, through what is now so well known to result from cylinder condensation. The three principal resources so far depended upon to ameliorate these losses have been superheated steam, high piston speed and the steam jacket. The effects, together with the limitations inseparable from the application of the first, are far better understood and more generally agreed upon than the utility of the last, or its availability or value under given conditions.

There is probably no subject connected with the steam engine upon which there has been, and is, so great a disparity of opinion, or in which such enigmatical or contradictory results are obtained from experimental research, as that of the steam jacket. As good evidence of this as can be desired may be found in Dr. R. H. Thurston's paper, "Authorities on the Steam Jacket; Facts and Current Opinion," read several years ago before the American Society of Mechanical Engineers. In it is very completely shown the great "diversity of view where concordance was expected."

Neither experiment nor speculation has done much, if anything, since that time to elucidate the problem of the prevention of cylinder condensation, and, while it will be scarcely possible, even by the most empirical sort of reasoning, to further obscure it, there remains the possibility that the merest speculation on the subject may open another pin-hole for the entrance of light upon this important question. It is now, perhaps, too long since Watt's dictum, "It is necessary to keep the cylinder always as hot as the steam which enters it," to be necessary to go into any considerable discussion of the generally accepted fact that the interior of the cylinder suffers a reduction of temperature both during expansion and exhaustion; that is to say, that in any cylinder of any steam engine the interior surfaces undergo a loss of temperature at all times while not in connection with the boiler, or with a preceding cylinder or reservoir, and that the subsequent contact of the steam from the boiler, or that exhausted from a higher pressure cylinder or reservoir, with the surfaces thus cooled, results in the liquefaction and deposition in the form of water upon the cooled walls of a portion of the entering steam.

Much speculation has been had on the value of the re-evaporation of this water during the expansion part of the stroke of the piston and the consequent recovery of a part of the heat value thus temporarily lost through the expansion work performed by it. As the reheating effect of the entering steam is, however, applied to the piston and cylinder head and the cylinder walls proper in

any economically working cylinder only through the comparatively short period during which the steam entrance or cut-off valve is open, the recovery of heat and its effect in producing expansive work can be had only from this smaller amount of surface previously reheated. Of course, it is understood that in such as the modern multi-cylinder marine engine, in which the cylinder diameters are large in proportion to the stroke, the total internal areas exposed to the entering steam previous to cutting off is comparatively larger than in many of the older types of engine in which the stroke bore a larger ratio to the diameter; but the fact remains that these larger areas of piston and cylinder head cause greater liquefaction and original loss of the entering steam because of their greater areas. These areas are subjected to the reheating and consequent liquefaction in a cylinder cutting off, say, at one-quarter, while the recuperative process of re-evaporation during expansion continues through nearly three times as long a period. It is to be borne in mind, however, that after the point of cut-off has been reached, the cylinder walls thereafter uncovered by the piston had not been subjected to the reheating effect of the entering steam, and are probably met by the expanding steam in a comparatively dry as well as previously cooled condition. At best, then, it is very probable that whatever saving, or prevention of loss, is effected through the expansive effect of the water re-evaporated during expansion is but a slight amelioration, if any, and can go but a little way toward rendering a prevention of the original liquefaction undesirable.

The great cooling effect takes place during the exhaust period, during which the interior of the cylinder is in communication either with the condenser or with the next lower pressure cylinder, or with the receivers, with which some designs are provided, and it is upon a portion of the surfaces thus cooled that the entering steam is liquefied. Dr. Thurston, in an earlier paper on this subject, read before the American Society of Mechanical Engineers, entitled "Philosophy of the Multi-Cylinder, or Compound Engine; Its Theory and Its Limitations," says: "The quantity so wasted varies with the weight of steam worked thermodynamically each stroke, with the area of surface exposed to this action, with the period of exposure, and with the range of temperature worked through during the cycle. It is, thus, always an increasing proportion when the ratio of expansion is increased, and as the size of engine doing a given amount of work is increased; it is diminished by increasing engine speeds and by any expedient which reduces the storing capacity of the interior of the cylinder. * * * The question which all engineers since Watt have been endeavoring to solve is—in what manner may we best proceed to eliminate or ameliorate this loss?"

So far there is little, if any, disagreement. It has been accepted from Watt's to the present time that the desirable thing is to avoid the liquefaction of the entering or expanding steam, or both, and since Watt's invention of the steam jacket the latter has figured as a means to that end beyond any other engineering suggestion. But, as we see, experimental and other authority is greatly divided as to its value under given conditions, or as to the conditions under which it is of the highest avail. There may be gleaned, however, from the work already done in investigating the steam jacket, a consensus plainly in favor of the value of the steam jacket in connection with the modern forms of engine in which steam of high initial pressure is used under a total high ratio of expansion, and, generally, that the more expansively the steam is used the greater is the availability of the jacket. From this it is plain that anything which may add to its efficiency in any case is much to be desired.

It would be a happy solution of the cylinder condensation question if it were practicable to generate, supply to and use in the modern high expansion engine steam superheated to such a degree that at the point of exhaustion into

the condenser it should be still above the condition of saturated steam, so-called, the thermodynamic work done, as well as the reheating of the cylinder from the exhaust temperature, being at the expense of the superheat alone. It is clear that in such a case, were there no external loss of heat, liquefaction of the steam would be impossible at any part of the stroke, and the great refrigerating effect of the re-evaporation of condensed steam would be absent. The reduction of temperature of the interior surfaces, and the consequent reheating to be done by the entering steam, would involve a loss of heat insignificant in comparison. It is well known, however, that, except in too moderate a degree to be of much avail with initial pressures of 150 to 175 pounds, because of the disintegrating and other ill effects of steam at such high temperatures as would be required, the direct use of superheated steam in this connection as the only means of preventing liquefaction is practically out of the question.

Aside from the use of superheated steam and the application of the steam jacket, the prevention of cylinder condensation has been sought in another direction—that of rendering the interior surfaces of the cylinder coming in contact with the steam as non-conductive of heat as possible. Examples of this are found in the experiments of Dr. Chas. E. Emery with glass or porcelain-lined cylinders ; in the patent recently taken out by Dr. Thurston for producing a graphitic condition in the surfaces of the cylinder heads and pistons in the process of manufacture, and in the older application of wooden linings to the cylinder heads and pistons. If these surfaces could by any means be rendered absolutely impervious to heat, no change of temperature in them could occur ; but, so far as known, the devices mentioned offer but slight amelioration of the difficulty, for the reason, probably, that it is but an infinitesimal depth of the metal, in any case, which has its temperature sensibly varied, and as at least some assignable depth of any material whatever must reach the temperatures severally and successively of the initial and the exhaust steam, or a close approach thereto, it is likely that making interior cylinder surfaces less conductive of heat can be of little avail. Besides, the mechanical difficulties in the practical application of this expedient on any ordinary scale appears to be well-nigh insuperable.

In the experiments of M. Dwelshauvers-Déry, at Liege University, Belgium, with sundry very ingenious apparatus, designed to render the behavior of steam in the cylinder visible, the following conclusions were reached : When that part of the apparatus which corresponded to the inner cylinder wall was allowed to assume a temperature considerably below that of the entering steam, large drops of water formed upon the surfaces. The higher the temperature at which this wall was kept, the smaller were the drops of water formed on it, and when the surface was heated to the same temperature as the initial steam, no deposition of water occurred. Subsequently, conforming his apparatus more exactly to the conditions of a cast-iron steam cylinder, he was enabled to determine that in a greater outer fraction of the thickness of the cylinder wall the temperature remained practically constant in any case, while in the inner and lesser fraction the temperature fluctuated periodically with the occurrence of a cycle, this fluctuation being greatest at the inner surface and diminishing outward until at a point, never far removed from the inner surface, the fluctuation became nil.

It is obvious, from these experiments, that any contrivance which will facilitate the supply of heat through the metal from the outside must operate to move the limit of temperature fluctuation nearer to the inner surface, and render the fluctuations less at that surface, and that when the external supply was sufficient to maintain the temperature of this surface such that it could not in its fluctuations fall below that of the entering steam, we would have simply the ideal condition required by Watt, and would keep the cylinder

"always as hot as the steam which enters it."

There are three factors involved in the accomplishment of this—the temperature and heat-evolving capacity of the external supply, the thickness of the metal of the walls and its conductivity. The first has been provided in several ways through the instrumentality of the steam jacket, but the last two factors seem to have received but little attention from engineers in this connection. It may go without saying that, with thinner cylinder walls, or with walls composed of better heat-conducting material than cast-iron, or, better, with both, the heating of the inner surfaces can be more easily and certainly procured, and with a much less difference of temperature between the jacket contents and the steam entering the cylinder, and such a temperature of the inner surfaces as Watt and Dwelshauvers commend, would be more easily maintained.

It is now well understood that the superior economy coming from high piston speeds is entirely due to the reduction in the fluctuations of temperature in the inner cylinder surfaces by the reduction of the cycle period, and that this economy comes thus from a lessening of water deposition within the cylinder from the entering steam. In other words, high piston speeds accomplish in a degree just what a supply of heat from the outside effects, and what is most in its favor is that it accomplishes this practically without cost, and is, therefore, so far as it is capable, the most efficient means of reducing the losses from cylinder condensation. Its capacity, however, in this direction is limited, and it can never bring about that ideal condition in which there will be maintained a temperature of the inner walls above that of the entering steam. Since, then, the thickness and heat-conducting capacity of the metal of the cylinder walls are such important factors in the maintenance of the interior surfaces of the cylinder at a temperature not less than that of the entering steam, in connection with the steam jacket, it may be asked why have not engineers looked or worked in this direction for a possible further improvement in its operation? The jacket has been found, in many cases, to be practically of little or no value, and it seems quite probable that in most such cases, the unsatisfactory results may be chiefly due to the inefficiency imposed upon the apparatus by the obstruction to the passage of the heat which it could otherwise supply, and which exists in the thickness and comparative non-conducting character of the metal of the cylinder walls. It is not difficult to see that, with a cylinder in which, for example, the cycle occupies less than half a second of time—a very common speed in modern propeller engines—the transmission of heat by conduction through from one to two inches of so comparatively poor a conductor of heat as cast-iron, must be very insignificant.

A function of the problem is, of course, to be found in the difference of temperature which, under some conditions, it is possible to maintain between that of the jacket contents and that of the initial steam, as in the circulation of more or less highly superheated steam through the jacket, or the still hotter chimney gases, as have been utilized in some instances. But, however greater a temperature may be maintained in the jacket, it still remains that, if we can facilitate the passage of the jacket heat through the cylinder walls, we avoid the difficulties involved in these high jacket temperatures, and operate in the direction of a nearer approach to the required temperature for the inner surfaces, which all agree to be necessary to wholly abolish the deposition of condensed steam upon them and the waste of energy resulting from its re-evaporation.

It does not appear so difficult a mechanical problem to so construct a steam cylinder and its heads, that a thin wall of brass, or similar good heat-conducting material may form the inner wall, and be secured at intervals, depending upon the pressures used, to an outer wall of cast-iron, the two forming and constituting the steam jacket between which the heating fluid may circulate.

It would, of course, be difficult to make any such provision for the piston, although supplying hot steam to its interior has been attempted. In the most exaggerated case of ratio of diameter to stroke, however, we would have a large proportion of the internal surfaces amenable to such treatment. In a low pressure cylinder, for example, of the modern type of tri-cylinder engine, of, say, 8-foot diameter and 4-foot stroke, the cylinder heads and exposable cylinder wall would constitute three-fourths of the whole on one side of the piston.

The writer has previously advocated experiments in this direction, but, so far as he knows, nothing of the kind has been attempted with the direct object of facilitating the transmission of heat rom a jacket to the interior surfaces of the cylinder; and he believes that experiment in this direction would show that the mechanical difficulties and extra cost of such a construction as outlined above would be much more than compensated for by the superior results which would be obtained. At all events, as an experiment easily tried, the cylinder heads alone might be thus treated and the performance compared with heads as ordinarily cast for steam jacketing. In a cylinder of the proportions mentioned above, about two-fifths of the interior surface exposed to the entering steam at the point of cut-off would operate in a single cylinder head under the proposed construction. From so simple an experiment as this it could easily be determined what value could be attributed to the general idea here advanced.

A NOTE ON COMPRESSED AIR.*

By Frank Richards.

COMPRESSED air has not received the attention which it deserves, and where it has secured some attention it has not always had fair play. There are many men in these days, and many intelligent engineers among them, who will not even consider the claims of compressed air as a means of power transmission because their minds have been so filled with the idea that its use entails enormous losses. That consideration settles it for them, and that is the libel from which compressed air suffers, so that it does not get a fair chance even to show what it can do. It is only another case of giving a dog a bad name, and in this case it is a very good dog with a very bad name. It is the worst kind of a case to set right. It is but common justice to tell the straight truth in the matter and to spread it as widely as possible.

The position of compressed air before the mechanical public, and especially the American mechanical public, has been a peculiar one all the way through. It has had no disinterested, all-around friends to look after its interests, nor interested ones either. There have been no men, and still less any company of men, who have made the application of compressed air their business and have looked after it. Where is the general compressed air company performing for compressed air such functions as more than one company is performing for electricity, and why is there not such a company? Of the builders of air compressors not one of them has been, not one of them is to this day, responsible for the economical application of compressed air after the compression, or apparently cares anything about it. Where compressed air has been used in this country, and where any thought has been given to economy in its use, the air compressor, it would seem, has been almost exclusively studied and talked about. In the progress of the steam engine it has sometimes seemed that the steam boiler has hardly rereceived its proper share of attention. In the existing writings upon steam engine economy it is probably safe to say that the engine engrosses ten times as much of the matter as the boiler does. In the case of compressed air the boiler, or compressor, gets ten times as much study and discussion as the engine or motor which uses the air. There are such vagaries of injustice in civilized communities.

This impression which has got abroad of the waste of power in the use of compressed air has, curiously enough, been promoted and disseminated by the air compressor people more than by any one else. We may say this with perfect safety, for it strikes so generally that it hits no one in particular. The compressed air literature accessible to the general public consists principally of air compressor catalogues. The argument of the average catalogue runs like this: "If you are going to use compressed air for any purpose look out for the enormous losses of power to be encountered and which you are sure to experience if you don't buy our compressor." And the result has been that many have "caught on" to the terrible tale of the waste of power, and have helped to spread it far and wide. The argument is, of course, not maliciously meant, but it has done more work and somewhat different work from what was intended.

Fig. 1 tells the whole story of compressed air. The piston F is fitted to

* From a paper presented before the American Society of Mechanical Engineers.

the cylinder *E*, so that we may assume it to move freely and without leakage. The piston being at *A*, as shown, and the cylinder being filled with air at a pressure of one atmosphere, and at normal temperature, a sufficient weight is placed upon the piston to force it down into the cylinder and compress the air contained in it to a pressure of say six atmospheres. The volume being inversely as the pressure, the piston should go down to *C*. We find that it actually only goes down to *B*, and the reason is that while the air is being

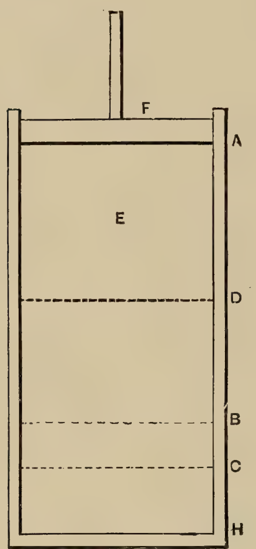


FIG. 1.

compressed the operation of compression also heats it, and the heat distends or expands the air, and its volume is consequently considerably greater than it should be upon the assumption that the volume is always inversely as the pressure. Supposing both the piston and the cylinder to be absolute non-conductors of heat, and that the air heated by the compression loses none of its heat of compression, then if the weight which forced the piston down be taken away the piston will be driven back to its original position at *A*, and the air contained in the cylinder will have resumed its normal pressure and temperature, and will have done as much work, or will have exerted as much force, by its return as was employed in the act of compression. If while the piston was at *B*, and with the weight upon it sufficient to balance the pressure of six atmospheres, the air by any means had been cooled to its original temperature, the piston would have fallen to *C*, and the law that the volume varies inversely as the pressure would have held good, as then the initial and the final temperatures would have been the same. The air being thus cooled to its original temperature, and the piston being at *C*, upon removing the weight from the piston it would return only to *D* instead of to *A*. When the piston arrived at *D* the pressure of the air in the cylinder would have fallen to the original pressure of one atmosphere, and the piston at *D* would be balanced between the equal pressures above and below it. As the air is heated during the operation of compression, so is it equally cooled during its expansion, and when the piston reaches *D* the air in the cylinder is then at atmospheric pressure, because it is then much colder than it was at the beginning ; and it is solely because of this loss of heat that the pressure falls so early, and that the piston does not return to *A* where it started from. If while the piston is at *D* the air can by any means recover all the heat which it has lost, the piston will return to *A* as before. The distance *DA* compared with *CA* represents the total possible theoretical loss of power in the compression and the re-expansion of air.

We may now consider the practical aspect of the case. Beginning at the very beginning, with the practical compression of the air, we cannot but notice how readily the air lends itself to economy in its use. By the way in which it is possible to connect the air-compressing cylinder with the steam engine in the best air compressors of the present day, no power is lost in operating the piston of the compressing cylinder, or, stated more accurately, the entire friction of the air-compressing apparatus is so compensated for by the

saving of friction in the engine that it is not only reduced to zero, but it becomes a negative quantity of considerable magnitude. This may be proved by incontrovertible evidence. The air compressor, it will be noted, comprises a complete steam engine, with all its component operating parts, steam piston, cross head, connecting-rod, crank-pin, crank-shaft, complete valve motion, etc., and in addition to these there is the air piston to operate, and it is natural enough to suppose that the operating of the air piston puts just so much additional friction upon the engine, with a call for so much more power to overcome it. But the arrangement of the air piston in a straight line and upon the same rod with the steam piston saves enough from the friction of the engine proper to more than compensate for the friction of the air piston, and the operating of the air piston costs practically "less than nothing." In a regular stationary engine which transmits its whole power through the crank-shaft, and by its driving pulley gears, or otherwise, wherever it may be wanted, the whole power exerted is felt in friction upon the cross-head slides, connecting-rod boxes, crank-pin, main bearings, etc. In the air compressor most of the power of the steam engine is transmitted directly from the steam piston to the air piston without the intervention of the engine friction. Not only is the effective steam pressure so immediately transmitted, but the force due to the inertia of the reciprocating parts, especially the heavy cross-head which is usually employed, is sent directly to the air piston through its piston rod.

The losses due to the friction of the ordinary stationary steam engine usually amount to 10 or 12 per cent. of the indicated horse-power. In an Ingersoll-Sergeant air compressor exhibited at Chicago, with engines of the Corliss type, the main friction, as determined by Professor Jacobus, was 5 per cent., so that, crediting the saving of friction to the air cylinders, the friction cost for operating them was — 5 to — 7 per cent.

The diagram, Fig. 2, scale 40, is intended to show the practical possibilities in the use of compressed air at 75 pounds gauge, or six atmospheres. The line *a b* is the adiabatic compression line, or the line of compression, assuming that no heat is taken away from or lost by the air during the compression. The initial temperature of the air being 60°, the final temperature would be about 415°, and the final volume is .28 of the initial volume. The line *a c* is the isothermal compression line, which assumes that all the heat of compression is got rid of just when it is produced, or that the air throughout the compression remains constantly at its initial temperature. The final volume in this case is .1666 of the initial volume. Remembering that these lines, *a b* and *a c*, represent the compression of the same initial volume of air, it is evident that there is quite a difference in the power employed in the two cases, and herein lies the loss, or the possibility of loss, of power in the operation of compression. The mean effective pressure, or resistance, of the air for the stroke on the adiabatic line *a b l* is 35.36, while the mean effective pressure for the isothermal *a c l* is but 27, or only 76 per cent. of the former. The comparison should, however, be made the other way. The adiabatic mean effective pressure is 130 per cent. of the isothermal mean effective pressure, and the 30 per cent. is, of course, the additional, or, as we might say, unnecessary, power employed. Neither of these lines, *a b* or *a c*, is possible in practice. Air cannot be compressed without losing some of its heat during compression, so that the actual compression line must always fall within the line *a b*. On the other hand, it is equally impossible to abstract all the heat from the air coincidently with the production of that heat, so that the actual compression line must always fall outside the line *a c*. The best air compressor practice of to-day is very near the line *a o*, or the mean of the adiabatic and the isothermal lines. The actual line is generally outside of this, and seldom inside of it. It would be

impossible to produce a line exactly coincident with this in practice. If we produced a line giving the same mean effective pressure as *a o*, it would probably run above *a o* for the first half of the stroke, and perhaps a little below it at the last. If the compression were "compound," or done in two cylinders, there would, of course, be a break in the continuity of the curve. The mean effective pressure for the line *a o l* is about 31.5, or still nearly 17 per cent. in excess of the mean effective pressure for the line *a c l*. As this is storage of the air, and the available volume is never practically above *c l*.

After the air has been compressed, and before it is put to use, it is usually transmitted through pipes for some distance, and the friction of the air in its passage through the pipe naturally causes some loss of pressure. Here again the air-compressor people have—unwittingly, we will say—done more harm than good as regards the interests of compressed air. Formidable tables are in all the air-compressor catalogues, showing the loss of pressure due to the

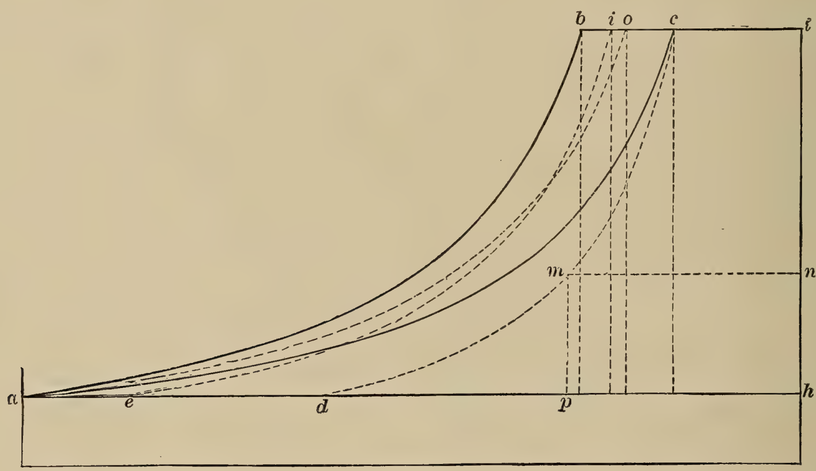


FIG. 2.

for what must be considered exceptionally good practice, the loss of power for the average practice in air compression may be put at 20 per cent. Lest some impatient ones should drop the subject here, or lest some rival of compressed air should pick up this and run away with it, we might insert a reminder here that all this loss is not necessarily final. It is proper to compare the actual compression line *a o l* with the ideal isothermal line *a c l*, because the volume *c l* is the volume available when the air is put to use. Though at the completion of the compression stroke there is always some of the heat of compression remaining in the air, and its volume is greater than *c l*, that heat is always lost in the transmission or the

friction of air in pipes, and timid investors, seeing them, have another fright. The tables are not dangerous, and are not published primarily for the purpose of frightening people away. They are only intended to suggest the size of pipe most suitable for any given case of transmission. If they tell us truly of the loss of pressure they still fail to tell us that the loss of pressure is not necessarily, or to the same extent, a loss of power. The actual truth is that there is very little loss of power through the transmission of compressed air through proper pipes to a reasonable distance, and the reasonable distance is not a short one. With pipes of proper size and in good condition, air may be transmitted, say, ten miles, with a loss of

pressure of less than 1 pound per mile. If the air were at 80 pounds gauge, or 95 pounds absolute, upon entering the pipe, and 70 pounds gauge, or 85 pounds absolute, at the other end, there would be a loss of a little more than 10 per cent. in absolute pressure, but at the same time there would be an increase of volume of 11 per cent. to compensate for the loss of pressure, and the loss of available power would be less then 3 per cent. This illustration is only offered as a simple and convenient one, and not as a sample of the best practice. With higher pressures still more favorable results could be shown.

Having compressed the air and conveyed it to the point where we wish to use it, we may turn again to Fig. 2 and see what we will be able to do with it. The air may be used in various ways with widely different economic results. Having the volume *c l*, and using it in a cylinder of suitable capacity, cutting off so as to expand down to one atmosphere before release, the adiabatic line or the lowest expansion line that the air could make would be the line *c d*, and the total loss in the use of the air, as compared with the power cost of compressing it, would be the difference between the areas *a o l h*, and *l c d h*, the latter being 66 per cent. of the former. The temperature of the air at *c*, where the expansion begins, being assumed to be 60°, the cooling of the air which always accompanies its expansion will bring the temperature far down the scale when *d* is reached, *d* being, of course, the end of the cylinder wherein the expansion takes place. The theoretical temperature of the air at the end of the stroke would be about—150°. The actual temperature is never found as low as the theoretical temperature, because the air receives heat from the cylinder and the walls of the passages with which it comes in contact, but it is usually still cold enough to cause serious inconvenience in practice, and unless some remedy be devised, this cooling of the air is fatal to its employment, entirely regardless of the economy of the case. The air almost invariably contains moisture, the amount varying with the surrounding meteorological conditions, and as the air becomes attenuated and so intensely cold the water in the air is rapidly deposited and frozen in the passages, and soon chokes them up and stops the operation of the engine. So it is useless to try to use compressed air generally, and with general satisfaction, without some means of heating the air immediately before it is set to do its work.

For some purposes the air may be and is constantly used without reheating. Hoisting, when done directly, and not by means of a hoisting engine, is, from its intermittent character, not likely to exhibit the freezing phenomenon. Besides the intermittent action of the hoist, giving time for the parts mostly to recover their temperature between the successive hoists, the air in direct hoists is not accompanied with the expansion of the air in the cylinder before its discharge, which expansion, where it exists, is productive of such intense cold. There is occasionally some trouble about operating rock drills on account of their freezing up, but not very often. They are more or less intermittent in their action ; they do not generally use the air with much expansion in the cylinder, and the exhaust is sharp and heavy. Many steam pumps are now run by compressed air without its being reheated, never with proper economy, but without their passages freezing up. They generally use low pressures of air, say 20 or 25 pounds, in a great many cases, and they carry a nearly uniform pressure for the whole stroke, so that if there is any trouble about their freezing up it is in the exhaust passage after the air has done its work, and jets of water or some other means of supplying a little necessary heat are sufficient to keep them going. The reheating of the air, where practiced, not only brings us out of our trouble about the freezing up of the parts, but it increases the volume of the air and its consequent available power at a very slight expense for the heating. If the volume of air *c l*, being now at 60°, be passed through a suitable heater and its temperature raised to 300°, its

volume will then be *i l*, instead of *c l*, or .2434 instead of .1666, an increase of volume of about 50 per cent. In practice, to insure a temperature of 300° in the cylinder at the beginning of the expansion, it will be necessary to heat the air considerably above that temperature, say to 400°, as the air loses its heat very rapidly. If now we use this air by filling the cylinder to *i* and then expanding down to *e*, supposing the temperature at *i* to be 300°, the theoretical final temperature will be about zero. The actual temperature, it is pretty certain, will not be below the freezing point, and all our trouble about the freezing of the passages will have disappeared and the power realized will have been much increased. The use of the reheater being so obviously a necessity we naturally should find it, in various styles, occupying a prominent place in the catalogues of the air-compressor people. Actually and unnaturally, we do not find such a heater in any catalogue, to my knowledge.

As to reheating the air, I may say, that a greater mechanical effect is realized from heat so applied than from any other known application of it, which consideration should urge us to extend its most economical use. There are many purposes, as, for instance, mining and all subterranean operations, where compressed air already must be used, regardless of all considerations of economy. There are many others, as, for instance, in general hoisting work, where it already pays to use compressed air. The extension of its use to the general purposes for which the steam engine, the gas engine or the electric motor are used is distinctly waiting for the general introduction of cheap, efficient, and, above all, "handy" means of reheating the air. It is quite practicable, by effective cooling of the air during its compression and by reheating it before its re-expansion, to bring the expansion line, *i e*, to inclose an area not less than that inclosed by the compression line *a o*, and then the entire losses will be those attributable to the clearances and to friction. In practice 85 per cent. of the initial power has already been realized after transmitting the air to considerable distances.

It was remarked above that the air after compression and transmission might be employed with widely different economic results. As an instance of how not to do it, I might cite the case, of too frequent occurrence, where air is delivered to a mine for operating rock-drills and other mining machinery, and then air is taken from the same line for operating a pump. This practice would be all right if the pump were adapted to the work to be done and to the pressure of air carried. The pump, however, is generally a common direct-acting steam pump, which has been obtained without any reference to the economical use of air. As it has probably already been run by steam, or is designed to be run by steam, it calls for a low operating pressure ; this being a necessity on account of the condensation of the steam when transmitted through long pipes. Say that the compressed air pipe carries 75 pounds pressure while the pump only requires 25 pounds. It would be an advantage, in a case like this, to use a pressure reducer in the pipe at a considerable distance from the pump, so that the expansion to the lower pressure required might take place, and the air have an opportunity to recover its temperature and volume before going into the pump. This, however, is seldom attended to, and the required reduction of pressure is effected entirely by the throttle at the instant of admission. Under circumstances far from the most unfavorable I have found pumps realizing only 15 per cent. of the power expended at the compressor, and I have no doubt that there are many pumps being operated, or whose operation is attempted, where not more than 10 per cent. of the original power is realized ; and even then, when the use of compressed air for operating such pumps is condemned, it is because the pump freezes up and will not go rather than on account of the enormous waste of power. From the fact that the duty of a mining pump is a nearly

constant quantity the pump, if properly proportioned and adapted to its work, should be an efficient missionary for compressed air rather than its most malignant traducer.

The word "loss," which we have been using in connection with this subject, is a somewhat incorrect and misleading one. The use of compressed air is for the accomplishment of a desirable purpose, and it is not to be expected that such a purpose can be effected for nothing. The transmission of power is as much to be paid for as the generation of the power. Where water-power is used the means of transmission may be the principal item of cost. Where the difference between the power expended and the power realized is not excessive, that difference is simply a fair price paid for a good service rendered, and there is no loss about it. Where losses do occur in the use of compressed air, they are like the losses which occur in business, and which cut short many a brilliant career. Power is lost simply because it is not saved, and the means of saving are not hard to find nor far to seek. The losses are not necessary nor unavoidable nor without compensation. It is a failure to understand and appreciate this situation which impedes the progress of compressed air.

There is a view of this question of compressed-air economy which makes it appear somewhat absurd. It is quite possible, as we have seen, to realize from our motor 80 or 85 per cent. of the power received at the air-compressing cylinder. In comparison with this what kind of a model of economy is the steam engine which is in such universal use? The consumption of water for supplying steam engines ranges from, say, 12 pounds per horse-power per hour up to 30 pounds, and away above that, and the consumption of coal per horse-power per hour from, say, 1½ pounds up to 8 or 10 pounds. One may stand in any city or large town in the country, and within a mile of him may be found an engine and boiler using over 400 per cent. of the coal per horse-power per hour which is used in the best engines, yet nobody goes around whining about the enormous loss of power in the use of the steam engine, or tries to discourage anybody from using it, or even seriously tries to promote a better efficiency. It is probable that the air-compressing cylinders of the principal builders of compressors do not vary more than 10 per cent. in the economy of their compression. I would hesitate long—and then, of course, refuse—to say that the economy of the steam end of the same compressors showed no more difference than that.

HOW MATERIALS ARE TESTED.

By Gus. C. Henning.

EVERY housewife, every butcher and every baker has methods of testing the materials or products which she or he handles, and, as is patent to all, never accepts any article until it has passed inspection. Who would buy a pound of butter without tasting, or a chicken or a goose without testing the strength of its bones? In fact, is there any article in common use which changes hands without inspection? Even a horse must show the color and character of his teeth before it is permitted to eat a new master's oats.

Similarly, many products of industrial works are tested and inspected, although it is amazing that the commonest materials of construction are rarely ever examined for their properties. It is only the exception that stone, brick, wood and the like are ever tested. When, however, products are put to trial, the testing is done in two ways; firstly, to determine the quality and properties of the materials used; and secondly, to determine the character or resistance of the finished article made therefrom. Thus, the plates and rivets to be used in a boiler are tested at the rolling mills where they are made, and when the boiler is complete it is tested as a whole.

Armor plate is first tested in the mill to determine the quality of the material, and the finished plate is subjected to the test of impact of ball or shell. Guns, again, are tested first, by testing small pieces cut from the tube and also the jacketing rings, while, when finished, they are subjected to heavy powder charges.

Again, material for pipes and tubes is tested before deciding that it has the desired characteristics, and the finished articles are then subjected to a different test to determine strength and staunchness.

One is the more critical and searching determination of the qualities of materials, while the other is merely a "working test." The former is intended to subject small pieces of material to such process or manipulation as to affect it in a manner similar to that to which it would be subjected when in use in a machine or structure. Hence, materials subjected to static loads in tension or compression are tested by the so-called tension or compression tests; while materials subject to impact or percussion are tested by the drop test; again, materials subject to bending are tested by transverse tests. In the case of natural and artificial building stones and their bond materials, it becomes necessary to apply other tests, such as the freezing and weather test and others, for it is well known that, although such materials may be able to carry heavy loads well, repeated action of rain and sun-drying, as well as freezing, make them unreliable and often perfectly useless. Sometimes a simple test may suffice to define with absolute certainty the quality and process of manufacture of the article, although in use the material may not be at all applied in a manner even analagous to that indicated by the test; *e. g.*, paper, in strips, tested by tension test, especially that used for bank notes. Enumerating the different kinds of tests, we find: (1) the tension test; (2) the compression test; (3) the transverse test; (4) the torsion test; (5) the drop test; (6) the hardness, or penetration test; (7) the abrasion test; (8) the cooking test; (9) the freezing test; and (10) the absorption test.

All of these have been fully investigated and give entirely accurate and

reliable results and data of scientific value. There are a number of others, which, although giving practical results in the hands of a trained operator, have not yet been so thoroughly studied as to give numerical values or comparable data. These may be classified as : (a) the bending test ; (b) the nicking test ; (c) the flattening, or spreading test ; (d) the shearing test ; (e) the punching test ; and (f) the drifting test.

The value of a test depends, of course, primarily upon the accuracy and reliability with which it is made ; hence, the methods and means employed become of primary importance. It is well known that materials cannot be accurately weighed when the balance is out of level or unbalanced, and when the weights are incorrect, or when the balance is out of order. It is imperative that the condition of all machines and the manner of using them and of making a test, be known before any reliable knowledge can be obtained.

(1) The tension test is one in which materials are loaded in tension or pulled until rupture occurs, noting at the same time all changes of form during the test and after its completion. (2) Compression tests are made to determine the resistance of materials to crushing, and are carried on until the material is completely crushed, as is the case when they are brittle ; or until smaller increments of pressures than previously carried produce greater distortions. In this case the highest load carried before failure and all changes of shape before and after that point is reached are carefully noted. (3) When it is desired to know what loads can be supported on "bridging," of whatever kind, the transverse test is applied, by loading a sample piece of material, supported on specified bearings, either up to the point of rupture, or until the loads produce such distortion that no further change of form can be produced. In this case all changes of form due to loads applied are noted. (4) When it is desirable to know what loads or work can be transmitted by revolving shafts, screw threads, nuts, etc., etc., the torsion test is resorted to. In this case the material is held at one end and the other is revolved about the axis of the specimen until rupture occurs, and the forces applied, as well as changes of shape during the test, are noted. (5) The drop test is used to determine the resistance of a material to impact, and consists of subjecting small test samples to the effect of a given weight, dropped from a fixed height, and noting the transformations due to each drop and that resulting from all of them together. (6) The hardness, or penetration test, serves to determine the resisting qualities of surfaces under pressures without motion between them. It consists in comparing the cutting capacity of a properly prepared edge, or surface, with the mineralogist's scale of hardness, in conjunction with the degree to which a point of definite size and shape will penetrate under given pressures. (7) In order to determine the utility of stone or brick or cements as pavements, sewer bottoms, embankments of streams, aqueducts and the like, the abrasion test is applied. This is nothing more than measuring the amount of material removed from blocks of the particular material when subjected continuously to the rubbing action of a harder material for definite periods, wet, dry and when frozen. (8) When, in the case of artificial stones or cements and mortars, it is desirable to know whether their volume remains constant, the "cooking test" is employed. This consists in immersing the material, after it has been allowed to set a sufficient amount, in water of a definite higher temperature for a given time, and then determining the changes of volume produced. (9) As cement and stone in structures are subjected to repeated saturation and drying, as well as freezing and thawing, these may have very considerable effect on them. The freezing test is used to determine in a short time what these effects might amount to in the course of time. Samples of the material to be examined are repeatedly soaked in water for definite periods, and changes in weight as well as amount of material dissolved or leached out are measured. Then these samples are frozen and

thawed a fixed number of times at given temperatures and under uniform conditions, and the effect and loss of weight by cracking, crumbling, etc., are determined. (10) The absorption test serves to determine the permeability of natural and artificial stone, tile and other building materials. Blocks of definite size and weight are dried and then immersed in water under uniform conditions, and the amount of water absorbed determines the percentage of absorption.

Of the remaining tests the first three are handy tests, quite commonly made, and of considerable comparative value; but as the conditions under which they are made are very varying and indefinite, considerable doubt as to results obtained always remains, though they may often take the place of more precise and careful tests. Concerning the last three, only meagre information is available, and they will, therefore, be merely described without further reference to them. (a) Bending tests are made either on a blacksmith's anvil or under a steam hammer, or an hydraulic press. Generally, a flat strip of material is slowly and uniformly bent until a certain degree of curvature is obtained; the amount of flexure possible is an indication of ductility. (b) The nicking test is similar to the bending test, except that the bar is first nicked to a certain extent by a chisel or saw cut and then bent, note being made of the angle of flexure at which the speciman breaks. (c) The flattening, or spreading test, is made on small pieces of the material, by hammering them on an anvil until the edges begin to show cracks. The amount of spreading indicates the degree of workability of the material. (d) The shearing test is made by measuring the amount of pressure required to shear off a certain section of metal by blades. (e) In the punching test the pressure required to punch a hole of given diameter is measured. (f) In the drifting test pins are driven through a punched or drilled hole, thereby spreading the material until cracks appear. The amount of stretch obtainable is supposed to indicate the ductility.

In making tests there are two points of the greatest importance, without which the results have but little value. The first of these is that the conditions in all tests be the same; and the second is that the method of making the tests and observations be alike. The first includes the shape of test piece. Inasmuch as our entire knowledge of qualities of materials are obtained by making comparisons, it follows that the basis for these must be identical; without similar bases comparisons are impossible. Two instances can be given to elucidate this point most clearly. When making tension tests it will be found that a cylinder of medium steel, of ½ square inch sectional area, will show a tenacity of 70,000 pounds per square inch; if another cylinder be cut out of this same bar, but of such diameter as to have but ¼ square in. sectional area, it may have a tenacity of 90,000 pounds per square inch. Another case is the following: Testing a strip of ½-inch boiler plate, 18 inches long and 1 inch wide, will show a tenacity of, say, 70,000 pounds per square inch. If this same width of test piece were obtained by drilling two holes opposite each other, so as to leave 1 inch of metal between them, the tenacity of this same steel might be found equal to 90,000 pounds per square inch.

Shape of test piece has a similar effect upon elongation of test pieces, and this is not only true of results of tension tests but equally of all others, though it is not always so easy to trace it. In making tests of all kinds it is also essential to know the correctness of the machines and apparatus used. In one case in the writer's experience a mercury gauge was used to determine the pressure of the water acting upon the piston which applied the loads to the material tested. When testing large wrought-iron bars in pairs, having a total cross-sectional area of 12½ square inches, this gauge would never show a higher reading than 2200 pounds per square inch pressure, which corresponded to a tenacity of less than 44,000 pounds per square inch without allow-

ing for frictional resistances in the piston and piston rod packing, and this in spite of the fact that the same iron had previously shown a tenacity of over 53,000 pounds per square inch, while the elongation was always practically the same. A number of similar tests convinced the writer that there was a radical error somewhere, and an examination revealed the fact that the tube of the mercury gauge had been broken off completely in the leather packing through which the tube passed in leaving the mercury reservoir. After a new glass had been inserted, similar bars were again tested with uniformly satisfactory results, showing a tenacity of 51,000 pounds per square inch, without allowing for friction. But previous investigation had shown that the friction amounted to 5 per cent. under such heavy loads, and, hence, a further correction had to be made, which gave a tenacity of about 48,500 pounds per square inch, which was about the correct strength in bars of the given size.

Another possible error, due to the method followed, and not to the apparatus, came to the notice of the writer several times, and is of sufficient interest to warrant mention here. It was desired to know the resistance of a certain column under different loads. These were applied partly by pressure by a press from above, and partly by a dead weight or gravity load. The pressure of the press was applied first, and when this had been carefully weighed, an equal load of material was placed on the column without removing the pressure due to the press. To the surprise of all observers the weighing machine did not show a load equal to the sum of the two, as expected, or double the pressure of the press, but only about 82½ per cent. of the sum of the two. A moment's reflection will show the cause of the discrepancy. In applying the first pressure the column was compressed or shortened by a slight amount, and a similar compression could have been produced by the dead weight of material alone; but when this was added after the pressure of the press had been applied, the column was still further compressed, thereby relieving a part of the pressure of the press. This may seem very simple after having given an explanation, but it has puzzled many an experienced mechanic and investigator.

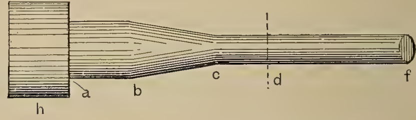
It may be well to instance a third case of error, to show how easily one may be deceived by observation. Many knife-edge machines carry a weighing platform directly, and loosely, placed on the first set of knife edges, thereby exposing them to accidental injury at the time of rupture of a test piece or under sudden shocks, due to recoil or impact. To lessen the danger of injury as much as possible, the weighing platform is held down on the knife edges by means of adjustable elastic buffers, such as blocks of rubber, springs, etc. By means of these an initial load can be placed on the knife edges and system of levers which is balanced by the counter poise, thereby causing the indicator to float freely at the zero mark, apparently indicating that the machine is in correct balance. Now as the platform becomes loaded, this initial load is gradually taken off the buffers and, although carried by the test piece, is not indicated by the beam. Hence, any such initial load tends to show less strength in the material tested than it actually possesses. In the writer's experience a certain specimen of wrought-iron showed a tenacity of 49,000 pounds per square inch, instead of 51,000 pounds as it should have shown, and actually did show as soon as the buffers were released, so as to merely come to a bearing, instead of applying an initial load.

The sensitiveness of the machines which are used while testing is an important point to be considered, for, although it is not necessary to exceed a certain precision in observations, it is essential to know up to what point the results can be relied upon. It would be unnecessary to observe great accuracy at one point if the same degree of precision were not obtainable throughout. Thus, measurements of cross-section, except in the most highly and correctly finished test pieces, are made by means of micrometer calipers read-

ing to $\frac{1}{1000}$ inch (and let us assume that this instrument is correct) ; now, the error of one-half of one thousandth inch when measuring a cylinder whose diameter is greater than 0.789 and less than 0.790 inches, amounts to 0.00124 square inches in 0.48892 square inches, or to about ¼ of one per cent.; therefore, it becomes useless to make observations finer than this degree of precision in conducting tests of strength or elongation. In the case of steel, such as is frequently used in structural work, and which has a tenacity of 70,000 pounds, a reading of load of 175 pounds (¼ per cent. of 35,000 pounds actual load) may be neglected, such load exceeding the greatest possible degree of accuracy. This load, + or —, means a variation in tenacity of 700 pounds per square inch. The above size is taken as an example, as it is the one most commonly used. The same accuracy of measurement in a smaller test piece, say 0.50 inch diameter, would decrease the greatest obtainable accuracy to 0.45 of one per centum, which shows the futility of making very fine observations of load.

However, the mistake must not be made to assume that greater nicety of observations need or should not be made in any case. When investigating the elastic properties of materials, the highest degree of accuracy obtainable should always be attempted, and the most delicate and sensitive apparatus should be used in making these observations. Bearing this in mind, it is not too much to say that but little reliance can be placed on observations of elastic deformation of materials made on most of the ordinary testing machines, unless the accuracy of the machine at all points of loading has been determined. It will be found that, although a machine may indicate a part of an ounce when unloaded, it may not be accurate within 100 pounds under a load of 30,000 pounds, and then require the addition or removal of 15 pounds before the indicator shows any sign of it or of motion. In the experience of the writer but two machines have shown greater degree of accuracy and sensitiveness than this, viz., the Wicksteed and the Emery machines, the latter, especially, to a most remarkable degree in both points.

Having indicated some of the more important directions in which to avoid error and use caution, we may now proceed to describe the tests previously enumerated under heads 1–10 and *a* to *f*. For the tension test, a piece of the material to be tested is prepared by machine tools, in such a manner that the part under test and observation shall have a uniform cross-sectional area with truly parallel sides or elements, and in case there are either heads or shoulders (the central part of the specimen only being finished to a standard shape) there should be a gradual change of shape from the smaller to the larger section, as it is well known that otherwise the results will be incorrect. To illustrate and make this point clear, let us look at the annexed sketch, representing one end of a standard cylindrical test piece, the other end being identical. In this, *h* is the head bearing on the holders by which stress is applied and weighed ; this merges by a neck or fillet *a*, into the shoulder *a b*, which again gradually merges, by the conical part, *b c*, into the cylindrical shape at *c* ; as this larger

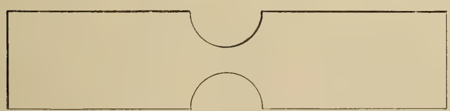


ONE END OF A STANDARD TEST PIECE.

part affects elongation, measurements of extension are not made from *c*, but from a point, *d*, distant one diameter therefrom, and called the gauge mark. The distance from *d* to the other gauge mark beyond *f* should be 8 inches, as all tests should be made on similar test pieces, and as this length has been found the most convenient and satisfactory. When, for any reason, this length cannot be used, and a longer or shorter piece becomes desirable, then it should always be so chosen with reference to its diameter that $l = 11.3\sqrt{f}$; in which $l =$ length on

which measurements are made, and f = cross-sectional area of test piece. With this precaution the results will always be comparable and only then.

When test pieces are cut from their shapes, such as sheets, plates, angles or channels, and the standard size cannot be obtained, it is advisable to use strips, either of uniform width and thickness throughout, or preferably of uniform width and thickness for a reasonable length, with heads or shoulders at each end, by which the strips are held in the machines. The length between the shoulders should be at least 8 inches, plus twice the width of test piece, plus one-half inch for fillets. When this length of 8 inches cannot be adopted, the length must again vary in a definite ratio, depending on the relation of thickness to width, always adding the extra length besides, as previously explained.



U. S. GOVERNMENT BOILER PLATE TEST PIECE.

When less length of test piece is used, the results, as far as tenacity, elongation and reduction are concerned, are generally incorrect and misleading; but when such shapes are tested as are prescribed for United States government tests of boiler plate, being merely a coupon strip with two half holes on opposite sides, as shown in the sketch on this page, then the results are absolutely untrustworthy and entirely without value. This fact cannot be stated with too much force and clearness, as it has been the cause of endless trouble and often calamity.

The effect of different lengths of test pieces on elongation, as commonly measured, is well shown in the illustration on the next page, furnished by J. H. Wicksteed, Esq., of Leeds, England. Two test pieces, *a* and *d*, 2 and 6 inches long between fillets, were cut from the same bar, and then strained in the testing machine until the maximum load which they could sustain was reached. They were then removed and photographed as shown at *b* and *e*. This done they were again put in the machine and strained to a point immediately preceding rupture. The specimens were then again removed from the machine and photographed as shown at *c* and *f*.

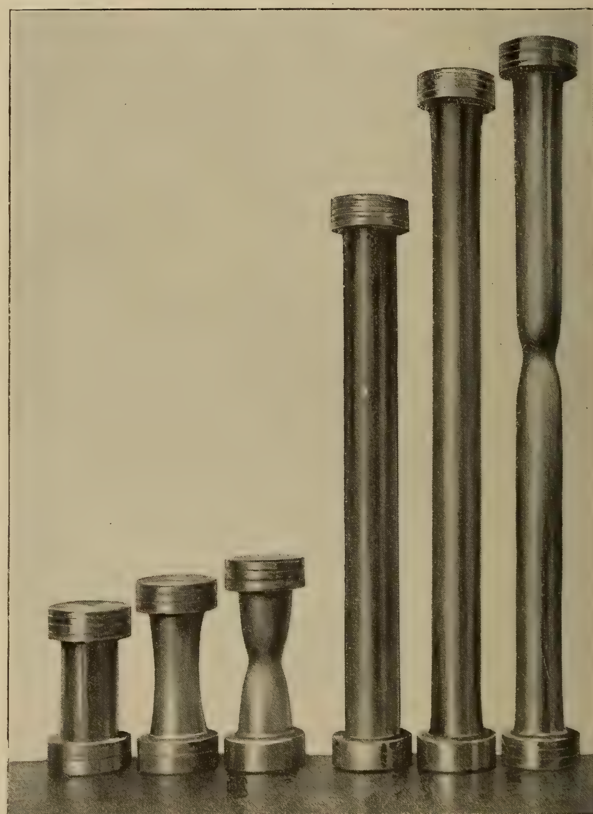
It is clear that the materials being identical should have given the same relative amount of elongation at all points; even a casual comparison, however, shows that this was not the case by any means. Measuring the specimen *e* showed an elongation of 25 per cent., while specimen *b* showed a slightly greater amount due to the effect of the heads at either end. But elongation is never measured until after rupture, and taking *c* and *f*, the total elongations were found to be 45.2 per cent. in the case of *c*, and 31 per cent. in the case of *f*.

The reason of these differences is that so long as the material reduces uniformity at all points of its length, the percentage of elongation is uniform for all lengths; and this is true up to the maximum load which any piece of material can carry. But immediately this load is reached, the test piece no longer behaves symmetrically, but begins to reduce very rapidly at one point only, and "necks down," as it is called. This local contraction takes place within two inches of length, and beyond this length the material is no longer affected by the loads applied, and, hence, neither contracts nor stretches elsewhere. This contraction is due to excessive elongation and is the same in every case, whether measured on a test piece of 2 inches or of 20 inches length. In the case of the pieces *a* and *d*, this local elongation was 0.36 inch; hence, 25 per cent. elongation of 2 inches = 0.50 inch; adding 0.36 inch local elongation = 0.86 inch total = 45.2 per cent.; and 25 per cent. of 6 inches = 1.50 inches; adding 0.36 inch local elongation = 0.86 inch total = 31.0 per cent. The proportional elongation, before local contraction, is in both cases practically 25 per cent.

All of this shows that a mere state-

ment of percentage of elongation without giving the length on which it is measured, does not answer as a basis on which ductility can be judged ; and also that percentage of elongation, when measured after rupture, is not a measure of ductility unless a proper correction has been made for excessive local elongation occurring during period of local contraction. This latter can be done by the use of certain mathematical formula, which, however, have not yet come into general use.* The simplest method to avoid all these difficulties and to avoid misunderstanding is undoubtedly to adopt one standard length of test piece. As shape in other directions exerts similarly important effects on the results of tests, it becomes imperative to make all tests on standard shapes, and even to sacrifice nearly all other conditions to this one, in all other as well as in the tension test.

Having determined upon the test piece we next proceed to place it in the jaws, holders, grips or shackles of a testing machine, and in such a manner that it will be in the precise axis of stresses, and remain there during the progress of the test. Having verified the correct balance of the weighing beam, the machine is set in motion slowly and the beam is kept balanced under the increasing loads until a change occurs in the behavior of the material. Such change may be indicated by apparatus attached to the test piece or with less certainty by the "drop of the beam ;" or else by cracking of the roll-scale when a rough or oxydized piece is tested. The application of loads produces stretch and consequently proportional reduction of cross-section, which is most readily observable, and as long as this is uniform the material undergoes no permanent change. As soon, however, as this rate of elongation changes, the material undergoes permanent change of form. Within the first period the material is practically permanently elastic, and hence, immediately beyond this is found that point which is called the "limit of elasticity." Proceeding with the test slightly further, it will be found that the material stretches very rapidly for a short period of time without increasing the stress, and this point is called the



a b c d e f

EFFECT OF LENGTH OF TEST PIECE ON ELONGATION.

* See Append. IV., Report of Committee on Standard Tests and Methods of Testing Materials, Transactions A. S. M. E., Vol. XIII.

"yield point." An instant later, however, the elongation increases only upon further loading, or addition of stress, and this continues uniformly up to the maximum stress which the material can sustain, and the change of shape up to this point is quite uniform. Test pieces of steel at that instant appear, as shown in *b* and *e* in the illustration on page 502. After this, the material will sustain less and less stress until rupture finally occurs, and during this period only local change of form takes place, extending over a very limited part of the specimen.

After the "yield point" is reached, especially in testing soft or ductile material, the rate of applying the load may be increased very considerably, and up to a point at which it remains possible to keep the weighing beam floating, but the rate must remain uniform. The amount of stretch measured before the elastic limit is reached is used as a measure of elasticity, and by dividing the load per square inch by the stretch per inch under that load, we obtain the "co-efficient of elasticity." It is well to measure the stretch on a standard length, and then always between the same limits of loading for the same material. This limit may vary for different materials, but if this precaution is not observed grave errors will arise and the results will again be non-comparable, and, hence, of little value.

Inaccuracies in these respects have led many prominent engineers and some college professors to assert that observations of co-efficient of elasticity are without value. The contrary is, however true, and the effect of different treatments of steel, for example, can be traced only by this means, as none but elastic properties may be changed by such treatment. Different engineers believe to have found steels of similar qualities showing co-efficients of elasticity varying from 22,000,000 to 35,000,000, and only because their methods and means of making observations have been defective. The "tenacity" of material is found by dividing the maximum load carried by the cross-sectional area of the test piece, and this should never be called "breaking strength," because, although it may be identical with the limit of elasticity in the case of hard or brittle material, it is altogether a different load from that at which soft or ductile materials break, being much lower.

After a test piece has been broken and removed from the machine, the cross-sectional area at the point of rupture is measured, and the difference between it and the original section, divided by the original area, gives the percentage of "reduction," although French engineers find the percentage of reduction by simply dividing the ruptured by the original area. It may be stated that in case of copper, soft alloys, very ductile bronzes, and manganese steel very strong, hard and tough, correct and reliable results cannot be obtained unless shoulders or heads are on the test pieces and a more or less gradual change of shape is given from the heads or shoulders to the bodies of the pieces. It has also been found that in the case of wood it is absolutely necessary to provide the test pieces with large heads and gradual necks in round as well as in flat test pieces Without this precaution the results will be unreliable.

Coming now to the compression test, it should be stated that there are two distinct tests under this general head, namely, the crushing test for materials which fail absolutely, becoming disintegrated, and the compression test proper, in which they do not disintegrate. For the former, cubes or cylinders are used which are as high as their greatest dimension of breadth. The materials are placed in a perfectly central position in the testing machine, having previously made their end surfaces absolutely parallel, and they may then be bedded on thin pieces of wood, leather, lead or copper; or, better than either, a thin layer of plaster of Paris, which insures absolute certainty of full bearing on surfaces. Care must be observed that the stresses are applied centrally throughout the test. The load at which the material crushes is the principal point observed. In com-

pression tests proper, columns or prisms of a length equal to 2, 10 or 20 times the diameter or breadth are used, and in these the shortening due to given loads is observed, as well as that load at which the material is rapidly and continuously distorted. Too much care cannot be exercised in placing specimens properly in the testing apparatus, as the slightest inaccuracy vitiates results.

In the transverse test, resistance to flexure is determined, and the usual form of test piece is a bar of rectangular section placed upon proper bearing, 6 inches, 1, 2, 3 and 4 feet between centres. The principal observations are the deflections due to given loads. The tests are continued either until rupture occurs or until the test piece is so much distorted as to slide through between the bearings.

The torsion test is made by holding the ends of cylinders or bars of material in such a manner that the one can be revolved about the axis of the material, while the other registers the resistance of the material to tortion and distortion. The test is usually carried along to actual failure of the material. The observations are the angles of distortion due to given loads transmitted, and that load at which the material fails.

The drop test is as valuable and accurate as the tension test, and consists in dropping certain weights from definite heights upon small cubes or cylinders of equal diameters and lengths. In this test the changes of shape in every direction, as well as the number and the force of the blows, is carefully noted. This test is probably the most handy and quickest of all, and gives reliable results for comparing great numbers of similar pieces of material at a minimum cost.

In the hardness and penetration test, pieces of material are scratched the same as minerals to locate their position in the well-known scale of hardness. Others are subjected to pressure applied to a hardened point, and the depth of penetration due to a certain load is the measure of penetration.

The abrasion test has been used mainly for road materials, and is made by revolving a mass of the substance to be examined, after having been put in the shape of a millstone, properly surfaced, under other materials subject to pressure. The amount of material removed during a definite period of time under the standard pressure is the measure of abrasion.

The cooking test is applied only to cements and mortars, and the amount of change of volume during a definite period, during which a cube of the material, after setting, has been immersed in water at a definite temperature, about 180° Fahrenheit, is a measure of the permanence of shape of the material when used in structures.

The freezing test is used to determine the resistance of stones and cements to atmospheric influences. Samples of the material are frozen and thawed repeatedly, about 28 times, and the amount of material lost or changes of shape produced during this test indicates the qualities of the material. These are still further determined by the absorption test. In this, a piece of material is thoroughly dried and weighed ; then the weight after continued immersion in fresh water at a standard temperature is again determined, and the difference between these weights gives the absorption.

The remaining tests are shop tests and are only valuable at the hands ot careful, experienced investigators. In the bending test, for example, strips of material are bent by hand, by hammer, or, preferably, by a steady-acting mechanism, and the angle to which the material can be bent around a given radius of curvature is considered a measure of ductility. When the samples, as for the bending test, are slightly nicked by chisel, saw or file before bending, the results will be more decided, and if, also, these pieces have been quenched in water at about 68° Fahrenheit, the results will be still more characteristic. In the flattening or spreading test, pieces of the material are struck by hammers on an anvil, and the extent to which the edges can be

thinned down before cracks appear, is also considered to be a measure of ductility. For the shearing test, pieces of material, except in the case of wood, are put under a shear blade, and the pressure required to shear off a strip is an indication of the "shearing" strength. In the case of wood, however, the best method of making the test is to cut a piece so as to leave two symmetrical heads, while the body of the piece is smaller. The shoulders are then placed in collars to which pull is applied, and the force required to strip the heads off the body of the piece of wood gives the shearing strength accurately. The punching test is made by measuring the force required to perforate a plate of given thickness by a punch of definite size over a die of fixed diameter. Very little is known about the value or accuracy of this test. In the drifting test, finally, a hole of given diameter is spread by forcing through it drift pins, under the action of hammers, until the outer edge of the material surrounding the hole shows cracks. The amount of stretching of the hole, up to this point, is considered a measure of ductility.

A. E. KENNELLY.

AMONG the several electrical engineers who have rapidly risen to prominence within recent years, Mr. A. E. Kennelly, whose portrait appears in this number, occupies a conspicuous position.

Mr. Kennelly was born in Bombay, India, in 1861, and it is from his father, at that time commander of a frigate in the East India navy, that he has inherited, in large part, his mathematical ability. He left India at an early age for the purpose of receiving an education in Europe, and finally entered the University College School, London. While at this institution, in 1875, his attention was turned to electricity, and on leaving the school in 1876, he became assistant secretary at the office and Ronalds Library of the Institute of Electrical Engineers, then the Society of Telegraph Engineers.

As a result of his studies at the Ronalds Library, he was enabled to enter the service of the Eastern Telegraph Company in 1877, and thence onward promotion was rapid. In 1880 he became assistant electrician on board the steamship John Pender, and in 1881 became chief electrician on board the same vessel. Later he served in the same capacity on several other vessels in the company's service, and was employed in work over all parts of the Eastern Telegraph Company's submarine cable system. It was during this period that he discovered the law of fault resistance known by his name, and which is now so much employed in cable testing, and in 1887 he published a paper on the subject which received the "Society's Premium" for that year.

In 1888, while senior electrician afloat of the Eastern Telegraph Company, he resigned his position to accept that of electrician to Edison, then just commencing work in his new laboratory at Orange, N.J., and was shortly afterward appointed consulting electrician to the Edison General Electric Company and later to the General Electric Company. Within the past year he left Edison's laboratory to enter upon electrical engineering work at Philadelphia with Prof. Houston, under the firm name of Houston & Kennelly.

Mr. Kennelly is a vice-president of the American Institute of Electrical Engineers, and is also a member of the New York Mathematical Society, of the Astronomical Society of the Pacific, an associate member of the Institute of Electrical Engineers of London, and a fellow of the Royal Astronomical Society. His work has covered a wide

field, though, because of his connection with the Edison company, necessarily but a small portion of his researches in electrical engineering has been published. Through the courtesy of that company, however, the results of his experiments on the heating of electrical conductors have been made available, and upon these almost all the tables at present in use have been based.

Among the more important instruments designed by him may be mentioned the differential dynamometer wattmeter—an instrument by which, the primary of a transformer being suitably connected to one set of coils, and the secondary to the other set, the losses in the transformer at any load may be read directly from the instrument; a static voltmeter now in use in street railway stations, which overcomes some of the difficulties met with in other forms of the instrument, and the ammeter bearing his name.

Besides having contributed a goodly share to the transactions of the several scientific societies with which he is connected, Mr. Kennelly is also the author of two books, one entitled "Practical Notes for Electrical Students," and a later one on "The Theoretical Elements of Electro-Dynamic Machinery."

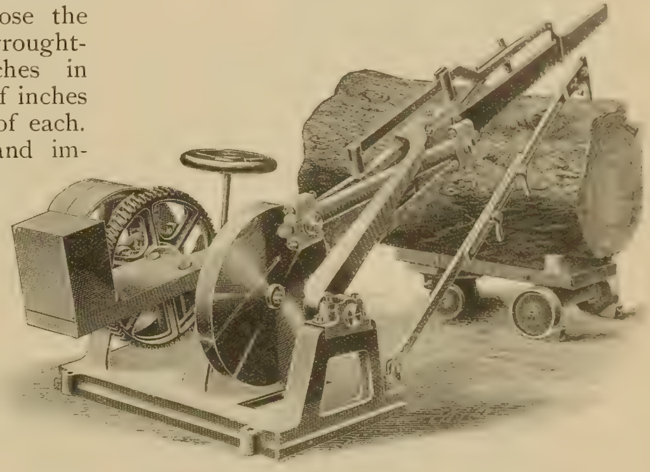
Current Topics.

Engraving by dynamite is the rather striking reference which has been made by one of the foreign journals to the imprinting of the lines of delicate leaves and grasses on metal surfaces by the explosive force of this material. A short time ago, so the story goes, a charge of dynamite was exploded by a board of army officers who had been delegated to test a new kind of fuse. In some way a small, dried leaf had slipped in between the dynamite cartridge and the iron block on which the charge was fired, with the startling result of a perfect imprint of the leaf in the metal. The most delicate lines had been reproduced with surprising distinctness, and further trials gave equally striking results. Leaves and flowers were placed between two plates of boiler iron and a moderate charge of dynamite was then fired on the upper plate. The exact outlines, with even the veins in the petals of the flowers, it is stated, were reproduced in the metal. While the truth of the account cannot be vouched for here, the results are quite within the range of possibility and it is not unlikely that more may be heard of them.

The thing, ot course, depends, in a great measure, upon the reaction effect

of the explosion and accordingly calls to mind one other service of unusual character to which dynamite has been put in the past, namely, the driving of piles. Several years ago, in the execution of municipal works at the city of Buda-Pesth, a number of piles, already driven, were required to support a greater load than had been originally contemplated, and it was consequently necessary to test them and drive those that yielded still deeper. To bring a pile-driving machine successively over each pile for so small an amount of work would necessarily have entailed considerable expense, and it was consequently determined to try the effect of dynamite. For this purpose the piles were cut square, and a wrought-iron plate, about fifteen inches in diameter and four and one-half inches thick, was placed on the top of each. In the centre of this plate, and immediately over that of the pile, was placed a charge of the explosive in the form of a cake, six inches in diameter, about three-quarters of an inch thick, and weighing a little over a pound. The dynamite was wrapped in parchment paper, covered with clay, and ignited, and the effect produced was found to be equal to that of about five blows from a 1500-pound monkey falling from a height of about ten feet. The iron plates, it was said, resisted from twenty to twenty-four explosions.

A RECIPROCATING saw, driven by engine power, and similar in some respects to the tree-felling and cross-cutting machine described in these pages a short time ago, has been brought out in England by a Halifax firm, Messrs. John Sutcliffe & Son, and appears to have proved itself to be a decidedly valuable labor-saving device, doing in minutes almost what the old hand-saw method took hours to accomplish. The machine is intended to be driven by a belt from a shaft carrying fast and loose pulleys and belt-shifting gear, and, though primarily designed for lumber yard use, may be mounted on a truck and carried directly into the woods for cutting up trees as they are felled, power in such instances being obtained from a portable boiler and engine. It seems quite unnecessary to enter upon any description of the machine, since its essential features are clearly shown in the accompanying illustration.



A NEW CROSS-CUT SAW.

WITH the advent of the big Ferris wheel at the Columbian Exposition last year, interest in big wheels generally began to grow and spread. One direct outcome of this was the final determination upon a mammoth wheel, also, as one of the features of the more recent exhibition at San Francisco, and the Firth wheel, as it was named, while not so large as its immediate precursor, proved itself a structure of commanding appearance and corresponding popularity. It afforded a magnificent bird's-eye view of San Francisco bay, the Golden Gate, the Pacific and ranges of surrounding wooded hills. Owing to the elevation of the grounds, the highest line of vision was 305 feet above the Pacific. The wheel itself was 100 feet in diameter, and with its sixteen cars weighed 192,000 pounds, while

the steel shaft upon which it rested weighed 18,000 pounds. The total capacity of the cars was 160 passengers. Unlike the Ferris wheel, which was driven by spur gearing, the Firth wheel was equipped with a rope system, similar in this respect to the "Gigantic" wheel at London, and the driving power was furnished by a 200 horse-power engine. About 20 minutes were occupied by a trip, and at night the wheel was brilliantly illuminated with incandescent lamps.

THE FIRTH WHEEL.

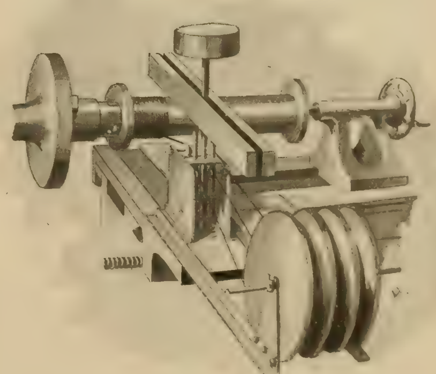
THE training of naval artillerists has, in recent years, been given a good deal of attention, and no end of powder and shot has been expended in target practice designed to serve a more telling purpose in actual warfare, should the occasion present itself. It would seem, therefore, that the floating equipments of naval powers of to-day ought to give good accounts of themselves in point of marksmanship if called into action, though it would be presumptuous to undertake to foreshadow possible results. If, on the other hand, past experience count for anything, there would seem to have been a notable decline in accuracy in naval gunnery, growing with successive improvements in naval architecture and naval armament. It was estimated some years ago, from data furnished by target practice at sea, that a heavy gun must be discharged fifty times to make one effective hit. The old smooth-bores were credited with killing a man by the discharge of the gun's weight in shot; in other words, three tons of 32-pounder shot were required for the purpose. Actual service test with modern high-power guns, however—guns weighing twelve tons—has, within the past ten or twelve years, shown that it took about sixteen tons of projectiles to accomplish the same thing. It is interesting to note from what statistics are available, that the introduction of rifled muskets into the armies has had a somewhat similar result. The old-time muskets, it is said, killed a man by firing at him his own weight in lead bullets, but the modern rifle in the hands of the average soldier, so it has been figured out, does not effect a fatality until it has discharged twice the man's weight in lead. Both here as well as in naval shooting, therefore, there has been shown to be an important demand for greater skill and care. Whether this has been met in any measure future hostilities only will tell.

CONCERNING the recent deplorable accident at the United States Navy Yard at Norfolk, Va., by which two men, who had sought shelter under a vessel in the dry-dock during a thunder storm, were killed by lightning, Lord Kelvin has taken occasion to say that to secure against danger men working under a ship in a dry dock there ought to be a thorough metallic connection, by wire rope or otherwise, between several points of the ship's iron, such as bollards, ring bolts, etc., and iron pipes leading to the water outside the dry dock. Similar precautions ought to be taken in respect to the frames of ships on the stocks in the course of building, although there is probably no previous case on record of an accident from lightning happening to men at work in the building of ships. An iron ship simply resting on wooden blocks, and without any connection by metal with the water of docks, or river, or sea in the neighborhood, is certainly,

according to Lord Kelvin, dangerous to persons standing on the ground and touching any part of the iron hull during a thunderstorm. It has been stated that precautions of the kind mentioned are to be adopted in all the English government dockyards.

SOME inventors are so exceedingly jealous of their own powers that when they have invented and patented, say, a coal shovel and undertake its manufacture, they must not only make the shovels, but make also the machines to make them. No ordinary machine will answer for cutting out the blank. It must be one of their own invention. Indeed, the metal must be rolled on a set of rolls which they have invented, different from anything that is made in any part of the world, and, if they could have their way, they would have their own iron mine, have a blast furnace of their own design, built from their own specifications, would work the metal in their own puddling furnaces—in fact, would not allow the ingenuity or inventive powers of others to diminish in any way the credit which should accrue to them from the invention of their remarkable shovel. This foolish idea, of not only inventing the thing but of inventing also the machine or machines to make it, is one of the rocks on which not a few companies have been wrecked. It is not necessary for every man to invent every piece of machinery that he puts into his factory, for the chances are that other inventors and other men have built just such machines as are wanted, and have made them a great deal better adapted to the work than would be possible for what may be called an amateur inventor. Captain Ericsson once said, in substance, that when other men have devoted much time and labor to a problem, their solution is much better than can be obtained by any single individual. Wisdom, then, dictates the accepting of the machines already perfected rather than, for the sake of originality, trying to find a substitute.

THE plan of serving over large copper steam pipes with wire wound on under tension as a means of reducing bursting danger to a minimum, has much to commend it, and, within the past year, has worked its way into favor with many engineers, so that now it may be said to be the rule almost, rather than the exception. The manner in which this method of reinforcement is carried out is, in itself, interesting, and is well illustrated in the accompanying sketch reproduced from The London Engineer, and showing very clearly how the work is done at the large establishment of Messrs. Yarrow & Co., the widely known English builders of torpedo boats. The copper pipe is mounted in a lathe, as indicated, and receives from three drums in front three contiguous belices of wire, the drums being carried along on a slide rest, which travels as in screw cutting. Each wire, on being paid off from its drum, passes over a grooved

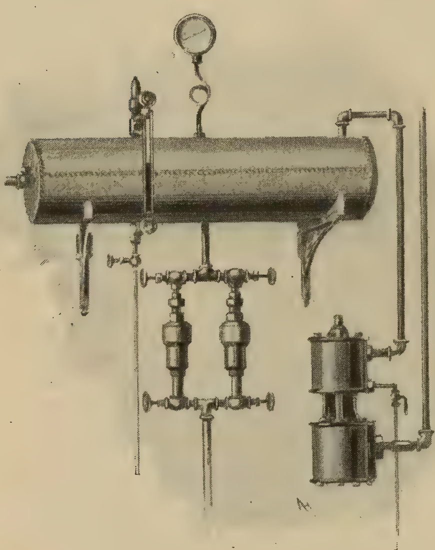


WIRING COPPER PIPE.

pulley as shown, thence passes downward, sustaining a weight, and finally passes over another pulley which is common to the three strands. From this last pulley the wires go directly to the pipe in the lathe. The weights maintain a tension sufficient to secure tightness, and by occasioning three sharp bends, produce a straightening effect, which is essential to the even-

ness and neatness of the job. The drums are held back by the operator, who watches the weights and exerts himself accordingly.

DISTRIBUTING commodities of various kinds—light, heat and power, for example, among a host of others—from central sources of supply, through underground and overhead pipes and wires, has become one of the striking features of latter-day engineering practice. It is interesting to note, however, that the idea has been worked out for successful operation not only on



A NEW LUBRICATING DEVICE.

large scales, but is applicable equally as well to installations of comparatively modest pretensions. A good example of this is furnished in a lubricating oil distributing system which is now in use in one of the large office building power plants at New York, and which was brought out a short time ago by the Wilson-Whiting-Davis Oiling Company of the same city. The little sketch annexed tells almost the whole story of the underlying principle of operation. There is, to begin with, an oil tank placed conveniently in or near the engine room, suspended either from the ceiling or from wall brackets, or, for that matter, placed upon the floor. This tank is only partly filled with oil pumped from a barrel or other reservoir, and its upper part contains air under pressure supplied by a Westinghouse air pump shown at the right of the illustration. The main oil outlet from the bottom of the tank is divided, as shown, into two branches, each fitted with an oil filter and each serving as a by-pass for the other, so that one filter may be always in circuit and in use while the other may be undergoing cleaning or repairs. The main outlet pipe extends several inches inside the tank above the bottom, so as to guard against the entrance of any foreign substance into the feed lines. The oil filter connections are provided with valves, so that they may be easily cut out of circuit. After having passed the filters, the oil is delivered by various pipe branches to oil cups or lubricators at the points where it may be desired on engines, dynamos and other pieces of machinery, and each cup or lubricator is provided with a separate valve, by means of which the quantity of oil to be delivered by it can be controlled. Each branch pipe also is controlled by a separate valve, so that, should one machine be idle, it would simply be necessary to close one valve in order to stop the feeding of all the cups on that particular line. The cups and lubricators have a spindle feed arrangement designed to secure a uniform and continuous flow of oil.

IT will be seen at once that the striking advantages of the system are that the feed of oil is equalized and constant; that separate cups are not required to be kept filled as with ordinary cup lubrication; that there is no danger either of running over and thus increasing waste, or running dry and thus heating the bearings; and that there is a saving of labor in attendance. Besides, there is said to be a decided saving in the quantity of oil necessary. The air pump is provided with a regulator so as to automatically maintain whatever air pressure may be necessary to insure

the desired flow of oil to different levels of machinery and against the pressure of steam in engine and pump cylinders, and all the attention required by the outfit is simply that involved in keeping a supply of oil in the main tank. Gauges on the latter indicate the pressure carried in the system and the level of the oil within. A small blow-off pipe extending from the bottom of the tank serves to remove any accumulations of sediment and water. The whole outfit is quite simple, and what experience has thus far been had with it would seem to have demonstrated its working results to be of a very satisfactory character. It represents one of the many additions to power plant equipments which have helped to increase efficiency and certainty of operation, and to reduce the care of petty details required of engine room attendants.

STEAM boiler inspection, as practiced in some of the large cities, has not kept pace with the demands made upon it. The New York system of police inspection, for example, was inaugurated in 1862 with 2000 boilers to look after. At present there are over 8000 steam generators in that city alone, and the number is constantly increasing. Under existing rules of inspection, the sergeant of police who has the matter in charge is obliged to grant a certificate of inspection to any boiler which stands a hydrostatic test of one-half more than the pressure which it is desired to carry. No provision is made in the rules of inspection for deterioration by age or hard usage, or for the results of poor workmanship and material. Such a system of inspection, while perhaps good enough for the low-pressure boilers of thirty years ago, in which only from fifty to seventy pounds pressure per square inch was maintained, is inadequate for modern steam generators with working pressures of 100, 125 and 150 pounds per square inch. The system of insurance inspection is much to be desired, and many boiler owners, in fact, insure simply for the purpose of obtaining the inspections. A more rigid law of inspection cannot well be devised than that of France, which not only minutely dictates the mode of construction, material and workmanship of each boiler, and closely defines a most exacting method of internal inspection and hammer testing, but also limits the size of boilers to be put into each building, and arranges the setting, connections and entire surroundings.

THE speed of a trolley car when passing any given point has been a matter upon the determination of which a good deal of discussion has been expended. To put a revolution counter upon the axle would solve the problem, but it is frequently desirable to ascertain the speed of a car without the assistance of a street car company. Particularly is this desirable when seeking evidence that the cars are being run at a higher rate of speed than allowed by law. It is well known that the motor gives forth a peculiar sound when the car is running. This sound Whittier in his poem on "The Broomstick Train" likened to the purring of a witch's cat, and it is in this purring sound that the speed indication lies. Whenever a number of blows or taps are delivered in regular sequence, they will, if their frequency be great enough, form a musical note. The reason for this is, that the ear cannot rid itself of one sound before another reaches it; consequently when the number of notes rise above a certain number per second, a musical note is the result. The eye possesses a similar faculty called "persistence of vision," which makes the firebrand give an apparently continuous circle of fire when whirled swiftly about. About one-sixtieth of a second is said to be the limit of persistence of vision, and 30 sound vibrations per minute are probably the least number which the ear can recognize. The lowest note on a 7-octave piano has about 33 vibrations per second, and middle C about 264. It is the striking or meshing of the gear and pinion teeth which causes the "purring" of the street car motor.

and if the tone caused by the meshing teeth has a pitch of "middle C," we know that 264 teeth are meshing per second. Then the number of teeth on gear being known, also the diameter of the car wheel, it is comparatively easy to calculate the speed of the car at the instant the sound observation was made, in spite of all efforts of the company to prevent the car speed from being known.

Illustrative of the ease and flexibility with which the electric current can be controlled, even when of great power, it may be interesting to note an electric switch which was recently completed, and is capable of turning on or off over 4600 electrical horse-power. The peculiarity of the switch lies not only in the fact that it may be used as a switch pure and simple, but that, as guaranteed by the manufacturer, it is capable of instantaneously cutting off this large power without any injury or harm. It is worth bearing in mind that in so doing, a current of 7000 amperes at 500 volts is interrupted. To instantaneously shut down a steam engine by means of an ordinary throttle valve would take quite some time, and would have to be more or less skillfully managed. Even if the steam engine were left out of consideration, and it were merely desired to shut off this amount of steam power, the task would have to be accomplished slowly, and the necessary valve for doing this would be of comparatively large size. With this electric "valve," however, this large amount of power can be turned on or off at once by the mere pulling or pushing of a lever. The switch is of the single pole, double-break type. The switching contacts have nearly 500 square inches of contact surface, and the entire device occupies a space of 15 by 12 by 10 inches. The switch is operated by a lever nearly three feet in length and can readily be worked by one man. It has never before been attempted to rapidly break an electric current of such large power, and the device will prove a feature of decided interest of the new station of the Philadelphia Traction Company.

Commenting on the growing introduction of ball bearings which, as may be remembered, first found practical use in diminishing the friction of bicycles, Dr. Coleman Sellers, in a lecture at Stevens Institute a short time ago, pointed out that one of the most notable examples of the use of balls is to diminish the friction of the collar that sustains the hook of a large crane. Without these balls the difference between the friction of rest and the friction of motion is so great that men are often seriously hurt by endeavoring to turn a load suspended upon the crane hook, which requires a great deal of exertion to start it, and when it does move, goes further than is intended, often leading to serious accidents. By making the crane hooks with flat washers, between which numerous small balls are placed, resting on hardened surfaces, there seems to be no difference between the friction of rest and the friction of motion, and hooks heavily loaded are turned with remarkable ease, so that the use of balls, distributed over plane surfaces, is quite common, there being no basket or grooves to separate the balls, which latter are allowed to move at their own will in whatever direction they are inclined to go. There is very little literature on the subject, and the theory of ball bearings has not been worked out and published. It may be interesting, however, to know that some experiments have been going on for some time past in reference to the size of the balls best suited to the different purposes. In the case of hooks for cranes carrying about 50 tons, between 250 and 300 balls, each of three-eighths inch diameter, are scattered between the flat plates, with the idea that the more points of contact the longer the balls will last, but some experiments are now being tried with balls of different sizes, and motion kept up under loads to determine their durability, with a leaning in favor of larger balls and fewer of them

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